A Spotlight Wonder Book

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INTO SPACE WITH THE ASTRONAUTS

Illustrated with official
National Aeronautics and Space Administration
photographs and drawings

INTO SPACE WITH THE ASTRONAUTS

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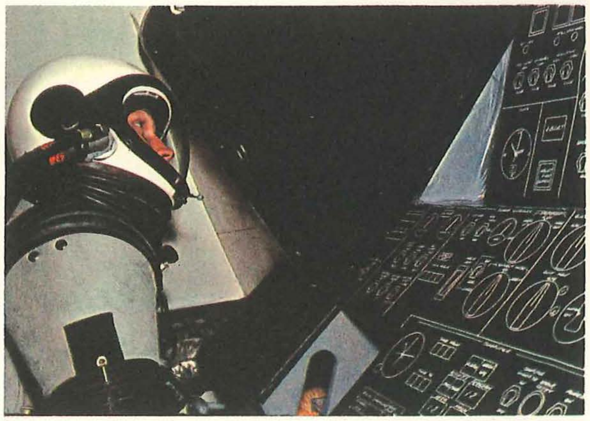

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Introduction

Men who have soared "into the wild *black* yonder" need no confirmation that we are in the Space Age. Is this an experience we can get secondhand? Probably not, yet reading *Into Space With the Astronauts,* each of us will identify with the astronauts and project our thoughts, like those of the astronauts, to future exploration of space.

The book is many things – biography, science, engineering, medicine, adventure. *It is not science fiction.* Ten years ago, it might have been. Now, astronauts are real, and in this book, we learn all about them. (Though astronauts are extraordinary in many ways, they are also people just like us – with homes, hobbies, likes, and dislikes.)

The spacecraft of the old science fiction are real now, too. We learn about the structure and operation of space vehicles – the Mercury, the Gemini spacecraft Pollux and Castor, and the Apollo spacecraft designed to put lunarnauts on the moon.

Very real, also, is a new science, astronautics. It is made up of many other sciences – astronomy, biology, physics, chemistry, mathematics, medicine, psychology. Thorough training in any one of these, or related, fields is a good preparation for an essential and rewarding job in the Space Age.

Into Space With the Astronauts reflects man's creativity and imagination in overcoming obstacles that stand in the way of exploring space. It helps the reader become a full-fledged member of the young – but already giant – Space Age in which men will take lunar steps and earth steps with equal confidence.

Paul E. Blackwood

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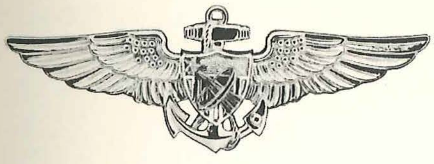
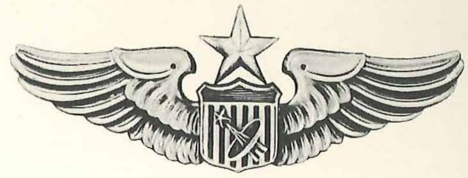


NAVY ASTRONAUT WINGS



AIR FORCE ASTRONAUT WINGS

The Making of An Astronaut

On the morning of February 20, 1962, Colonel John H. Glenn, Jr., was awakened from his sleep at 2:20. Quickly, he showered, shaved, and ate a breakfast consisting of orange juice, scrambled eggs, toast, jelly, steak, and tea. Next, he reported for his pre-departure medical examination. This time, the doctor came to him.

The doctor's verdict: "Go."

Next on the schedule was the long suiting-up procedure and then the short ride from the sleeping quarters to the launching pad. Crewmen working in the launching area could see Colonel Glenn smile behind his space visor as he walked briskly to the gantry (a huge service tower) and ascended by elevator to its top. From here, he crossed to and entered a bell-shaped object mounted atop a great Atlas rocket. Five minutes later, the door of *Friendship-7,* the name painted on the side of the spacecraft, was closed.

For the next three and one-half hours, Colonel Glenn lay on his back in a form-fitting couch, making his final checks of the flight instruments while launch preparations continued. At 9:47 A.M., fire and smoke appeared under the tail of the Atlas. The mighty 130-ton rocket, trailing a bright white and yellow flame, rose slowly from the launching pad. With a roar, it went streaking skyward, a thin white vapor trail following. Within seconds, it was gone.

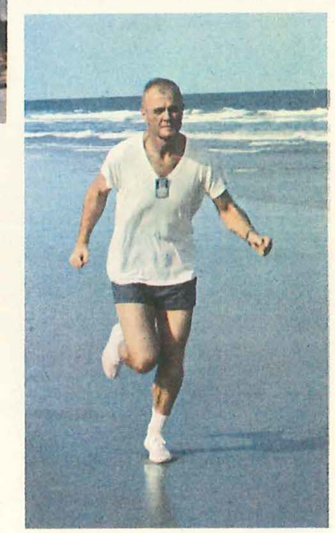
From his spacecraft perched on top of the speeding Atlas, Colonel Glenn reported, "Lift-off. The clock is operating. We are under way." Just 301.4 seconds after he had left the earth's surface, John Glenn was in orbit. America had sent her first astronaut into space.

What is an astronaut?

While science fiction writers have been using the word "astronaut" for years, it didn't become part of the average American's vocabulary until 1959, and only very recently gained recognition in our dictionaries. For instance, one dictionary defines "astronaut" as (a) "a student, devotee, or advocate of astronautics — the science of space flight"; and (b) "a traveler in extraterrestrial (beyond earth) space." The Russian term "cosmonaut" has the same meaning.

A common misunderstanding is that the word applies only to pilots of spacecraft. If we look at the dictionary's definition again, many others can also properly be called "astronauts." It describes the navigator, support-crew member, engineer, technician, scientist, physician, or even a passenger (if he is a traveler in space). Thus, the astronaut profession is the newest and most inter-

The seven astronauts chosen for our first space mission take flight training in the newest jets available. Left to right: Malcolm Scott Carpenter; Leroy Gordon Cooper, Jr.; John Herschel Glenn, Jr.; Virgil Ivan (Gus) Grissom; Walter Marty Schirra, Jr.; Alan Bartless Shephard, Jr.; and Donald Kent Slayton.



All astronauts are active in outdoor sports. Our picture shows John Glenn taking his morning exercise with run on Cocoa Beach, Fla.

esting of the Space Age, the age that began on October 4, 1957, the day the Russians launched the first man-made earth satellite, *Sputnik I.*

How are astronauts selected?

"WANTED — VOLUNTEERS FOR SPECIAL MISSION. Must have experience as test pilot and jet pilot, plus at least 1,500 hours of flight time. Bachelor degree or its equivalent in engineering or one of the physical or biological sciences required. Must be under 40 years of age, be no taller than 5 feet 11 inches, and weigh no more than 180 pounds."

While the National Aeronautics and Space Administration (NASA), the governmental agency in charge of the United States space effort, never printed a "help wanted" ad like this, it requested from the commanding officers of our three military services, the Air Force, the Navy, and the Marine Corps, the names of men who would meet these qualifications. After studying the records of the various men recommended, NASA selected about 100 pilots and called them to Washington for personal interviews.

From all over America, and from overseas bases, these men arrived at our nation's capital, completely unaware of why they were ordered there. But they soon found out. The United States was going to try to put a man in space. Would each care to volunteer to be that man if the NASA selection board thought that he was good enough for the task?

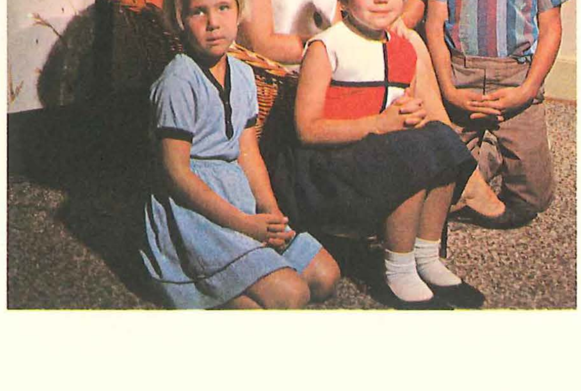
While a few of the pilots refused for good reasons of their own, the majority were elated by the prospect of being the first American in space. First, these men were asked detailed engineering questions calculated to test their knowledge and then quizzed on the achievements of their past careers. Psychologists questioned them about their personal lives and their reactions to all sorts of things — from how they felt flying jet airplanes to the way they had felt as children about their own parents. After all these tests, 32 candidates were chosen.

How many astronauts were chosen for our first space mission?

But 32 men, even though highly qualified, were more than NASA could use at that time; it had been decided to limit the final selection to seven. Therefore, more tests had to be given. These included the most thorough physical examination possible. For over seven days, the men were probed and prodded. Their stomachs, hearts, glands, circulatory systems, and kidneys were all checked with the ut-

The first seven astronauts are seated. Standing from left to right is the "space flight team 1962": Edward H. White, II; James A. McDivitt; John W. Young; Elliot M. See, Jr.; Charles Conrad, Jr.; Frank Borman; Neil A. Armstrong; Thomas P. Stafford; and James A. Lovell, Jr.

In October, 1963, NASA introduced 14 new astronauts (7 volunteers from the Air Force; 4 from the Navy; 1 from the Marine Corps; and 2 civilians). Standing from left to right: Michael Collins; R. Walter Cunningham; Donn F. Eisele; Theodore C. Freeman; Richard F. Gordon, Jr.; Russell L. Schweickart; David R. Scott; Clifton C. Williams, Jr.
Seated from left to right: Edwin E. Aldrin, Jr.; William A. Anders; Charles A. Bassett, II; Alan L. Bean; Eugene A. Cernan; Roger B. Chaffee.



All our astronauts are married, and all have children. This is the family of Astronaut Carpenter, second American to orbit the earth. Carpenter's wife, Rene, poses with their children. From left to right: Candy, Kristy, Scott, Jr., and Jay.

most care. Their eyes were examined, they were X-rayed, and their brain waves measured. The doctors were looking for those who were in the very best physical condition.

They were tested for how well they would stand up under great physical exertion and how capable they were of making sound decisions under conditions of mental stress. For example, in a test that determined an astronaut candidate's reactions to stress and fatigue, he was placed alone in a totally dark, soundproof room that contained only a comfortable chair, a bed, toilet facilities, and a refrigerator stocked with food. The candidate remained in the room for up to 48 hours while doctors and psychologists observed his reactions to the darkness and loneliness. The observers gave the highest ratings to the men who had enough imagination to find some way to make their isolation as pleasant as possible, such as working out a mathematical problem or composing poetry. Low ratings went to the candidates who just sat and thought, and who later could not remember how they had spent their time.

When all the tests were over, the exhausted candidates went back to their military stations. They were, without a doubt, the most tested men that ever lived. After the NASA selection board had carefully studied and re-evaluated the results of the various tests, they made their choices known on April 9, 1959. They were: Capt. L. Gordon Cooper, Jr., Capt. Virgil I. Grissom, and Capt. Donald K. Slayton, U.S. Air Force; Lt. Comdr. M. Scott Carpenter, Lt. Comdr. Walter M. Schirra, Jr., and Lt. Comdr. Alan B. Shepard, Jr., U.S. Navy; Lt. Col. John H. Glenn, Jr., U.S. Marine Corps.

Have more groups of astronauts been selected?

NASA changed its requirements somewhat for the nine additional astronauts selected for the "space flight team" in 1962. The candidates could be as tall as six feet, but they had to be no older than 35 years of age. They still had to be jet test pilots, but civilian as well as military experience was acceptable. Since 1962, a number of new men have been added to the teams of astronauts and, as the United States program expands and becomes more complex, we may well have over 1,000 by 1970.

As the need for space volunteers increases, the requirements for an astronaut may become even more flexible. For instance, NASA plans to use civilian non-pilot personnel with advanced college degrees in science and engineering in the near future. Also, many of the physical and psychological tests given the early astronauts will be dropped. But the candidates will still have to undergo extensive physical examinations and interviews. Maybe, in a short while, the United States will even have an equivalent to the Russian Valentina V. Tereshkova, the first woman cosmonaut.

What are the astronauts really like?

No one member of the space flight team can be called "the average astronaut." However, an average has been taken of some vital statistics of the original seven and the second group of nine. The aver-

age height of the 16 men is 5 feet 10 inches; the average weight, 160½ pounds; the average age, 35 years; and the average flight time recorded, more than 1,200 hours in conventional aircraft and more than 1,800 hours in jet aircraft. Additionally, each man of the group has at least one degree in science or engineering.

Probably, the most unusual thing about the astronauts is that they lead such "usual" or normal lives away from their work. All are married, and all have children. They watch television, and like to read. While they all are active in outdoor sports, some prefer to fish or hunt; the others enjoy water sports such as swimming, skin diving, and water skiing. Astronaut Shepard, the golfer of the space team, says he can't wait until he can play his favorite sport on the moon. (Do you know why? The answer can be found on page 25.) Each spends as much time as possible with his family and, like the average American, helps do the weekly shopping with his wife in the local supermarket. They participate in Boy Scout activities, both in active and consulting roles; figure in community affairs; and belong to professional organizations such as the American Rocket Society, the Society of Experimental Test Pilots, and the Institute of Aerospace Science.

The astronauts work directly for NASA. Most of them live near the Manned Spacecraft Center in Houston, Texas. The astronauts who have been selected from the armed services are paid according to the military pay scale, depending on the individual's rank and branch of the armed services.

What were the accomplishments of the early astronauts and cosmonauts?

The men who were first to brave the dark pathways of space are our new heroes — and will ever be such to grateful mankind. Russian Cosmonaut Yuri A. Gagarin officially opened the Space Age on April 12, 1961, when, as the very first man to travel in space, he orbited the earth a single time. The flight into space of Astronaut Shepard on May 5, 1961, was equally thrilling to a waiting, watchful world. On July 21, 1961, Astronaut Grissom made a second suborbital flight for the United States. Just four months later,Cosmonaut Gherman S. Titov won his niche in eternity's hall of fame as the second man to circle earth in space. A great new chapter was written into the space story on February 20, 1962, the red-letter day that Astronaut Glenn successfully completed a three-orbital flight.

More heroes, moving courageously and swiftly, appeared on the scene — Astronaut Carpenter, who circled the earth three times in 1962; Russian Cosmonauts Nikolayev and Popovich, whose dual flight that same year whirled Nikolayev around the earth all of 64 times; Astronaut Schirra, who, in that memorable year, also orbited six times; Astronaut Cooper, who closed the U. S. Project Mercury program in 1963 in a blaze of glory with a 22-orbit, 34-hour mission! 1963, too, was the year a woman cosmonaut, Valentina Tereshkova, in *Vostok VI,* orbited 48 times, and Lt. Col. Bykovsky made 81 orbits in *Vostok V*! In late 1964, the *Voskhod* (carrying Col. Komarov, its pilot; K. P. Feoktistov, engineer-scien-

tist; and Lt. Yegorov, a doctor) made 16 orbits in 24 hours 17 minutes as the first spacecraft to carry more than one person.

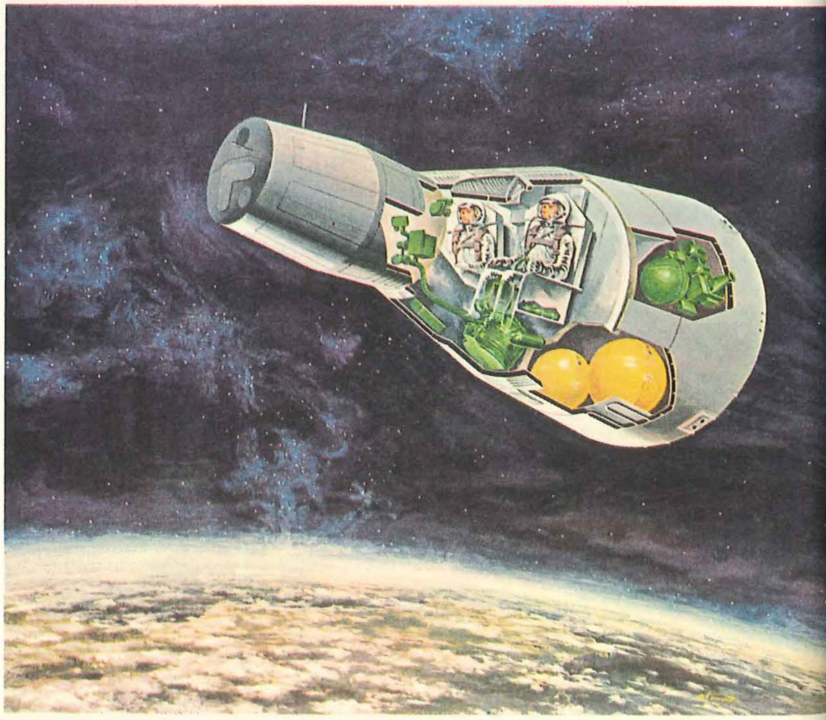
What is the challenge of space?

Although the first astronauts and cosmonauts set the stage for greater adventures in space, the great challenge of space is still before us. With the completion of Project Mercury, our first space program, and the Russian *Vostok* flights, it has been proven that we can get man into space, keep him there, and return him to earth safely. Our next objective, which we hope to realize by 1970, is a trip to and from the moon.

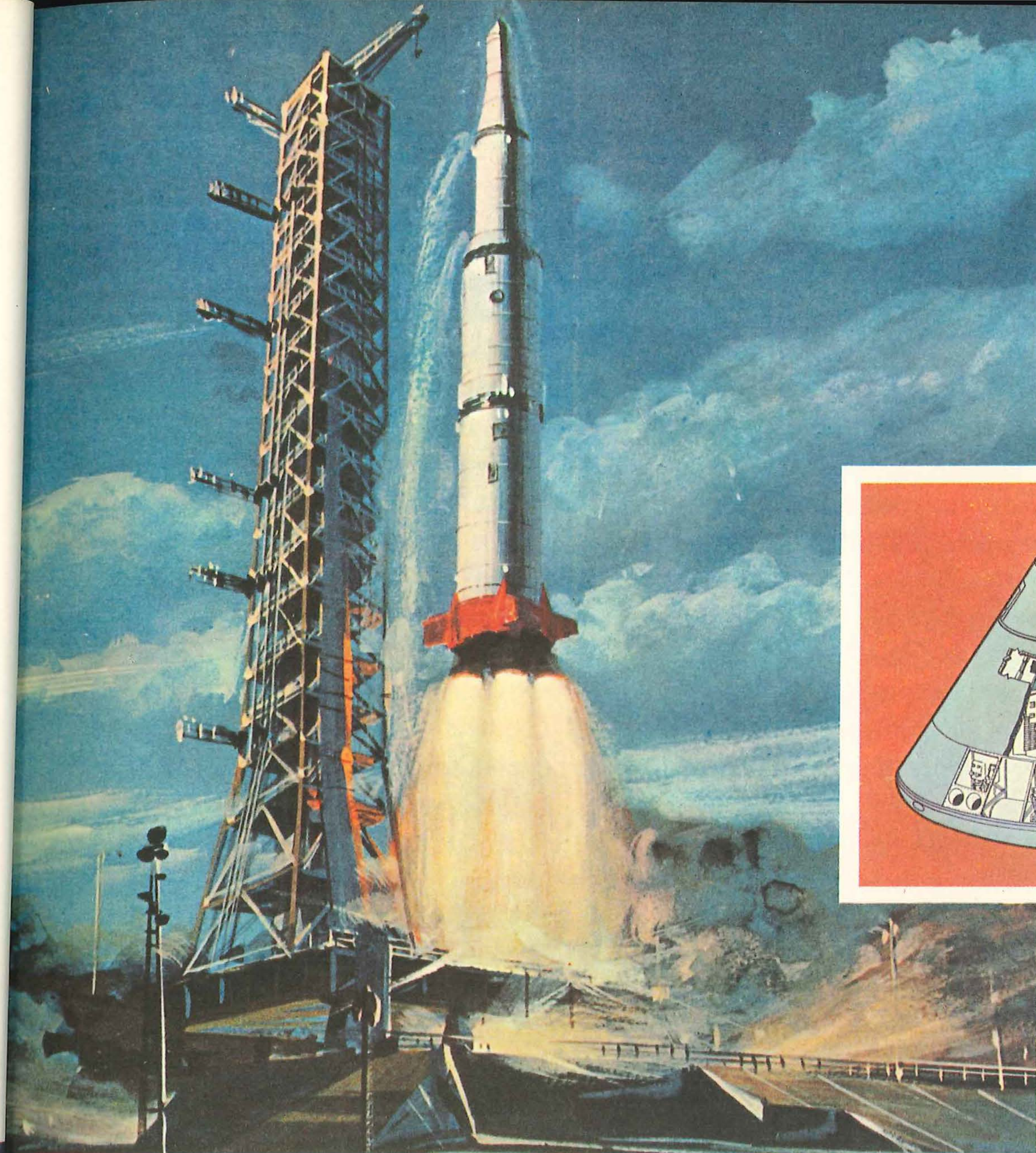
To achieve this goal, the United States now has two programs—Project Gemini and Project Apollo — under way. In Project Gemini, the astronauts will learn how to connect or dock one spacecraft against another while in orbit and how to live in outer space for extended periods of time. This is in preparation for Project Apollo, the actual flight to the moon and back. We will deal with these programs in more detail later in this book.

From the very beginning of Project Mercury, space exploration has often been compared to Columbus' voyage in 1492. There are grounds for such comparison — the great skills and risks involved; exploration of the unknown and uncharted regions of the universe; and a broadening of man's knowledge

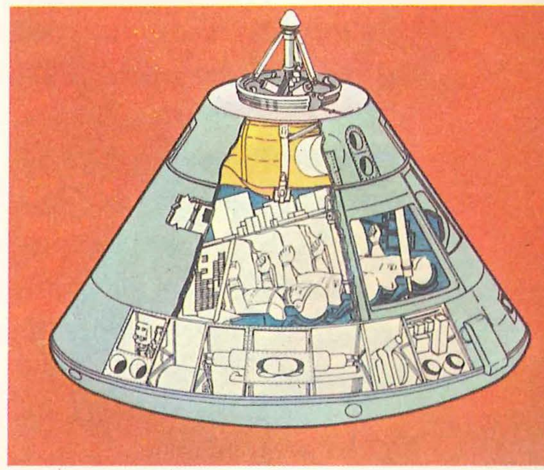
This is an artist concept of the Mercury spacecraft showing cutaway view and also the escape tower and retrorockets.



This cutaway shows a two-man, two-week orbital space vehicle of Project Gemini.



Artist's concept of the blast-off of the Saturn V; 7½ million pounds of thrust lift off its pad the vehicle carrying three astronauts of Project Apollo to the moon.



Artist depicts Apollo Command Module.

and thinking. Yet, with full respect to Columbus' venture to the New World, there are many features of space exploration, as you will learn later in this book, which raise it above the level of even that historic feat of the 15th century. While we will not attempt to compare the courage of Columbus and his men to that of our astronauts, it is fair to say that the latter are fully dedicated to pioneering in space travel and offer their collective talent so that man can learn more about the moon, the planets, and the rest of the universe. The late President John F. Kennedy, describing space as "a new ocean," called the astronauts "the admirals of that ocean." Even the names "astronaut" and "cosmonaut" also recall Columbus and other sailors who first crossed the oceans. "Astronaut" is derived from Greek words meaning "sailor of space," and "cosmonaut" from Greek words meaning "sailor of the universe."

Astronauts in Space and on the Moon

Man has been defying the elements since he appeared on earth. Driven by the instinct of survival, by his love of adventure, and by curiosity about the unknown, he has braved the oceans, the mountains, the deserts, the skies, and finally, space. But, reaching out into space, man faces more terrifying, complex demands on his body and mind than ever before. He has faced many of the problems separately, but never all of them together. In airplanes and atop high mountain peaks, his body has screamed out for oxygen; in jets, he has endured (for a short time) crushing g-forces; in other planes, briefly, he has floated weightlessly like a Ping-pong ball; in submarines, he has endured prolonged isolation; in the Antarctic, he has known the bone-wracking pain of sub-zero cold; and in the equatorial zones, or close to fires, he has been shriveled suddenly by intense heat. He has, however, never faced these critical conditions all at once. He may never have to, but, as an astronaut, he will have to be prepared to endure them and survive when traveling in space.

What are celestial mechanics?

Before we look at what the astronaut's life will be like in space and on the moon, we must first understand a little about the celestial mechanics of space flight. The science of celestial mechanics is the study of motion in space, whether the object in motion is natural or man-made. While it is a very extensive science, we will confine ourself to our own solar system and its gravity.

Sir Isaac Newton, the great 17th Century English scientist, formulated the law of gravitation, which is concerned with the mutual attraction, or "pull," that exists between all particles of matter. In its simplest form, Newton's law says this:

1. All bodies, from the largest planet in the universe to the smallest particle of matter, attract each other with what is called a "gravitational pull."
2. The strength of their gravitational pull depends on their masses.
3. The closer two bodies are to each other, the greater their attraction to each other.

Earth has a gravitational pull. It pulls anything within its range toward its center at increasing speed. The theoretical value of gravitational acceleration at the earth's surface is used as a basic unit of measurement known as one gravity, or one g.

Earth's gravitational influence is believed to extend throughout the universe, although the force weakens with distance and, from a certain point on, becomes virtually impossible to measure. Any spacecraft or vehicle moving in space is subject to gravity. The vehicle, having mass, is itself a space body. Therefore, it attracts and is attracted by all other space bodies. The degree of attraction, however, of distant bodies is too small to require consideration because they are too far away. But spacecraft moving between the earth

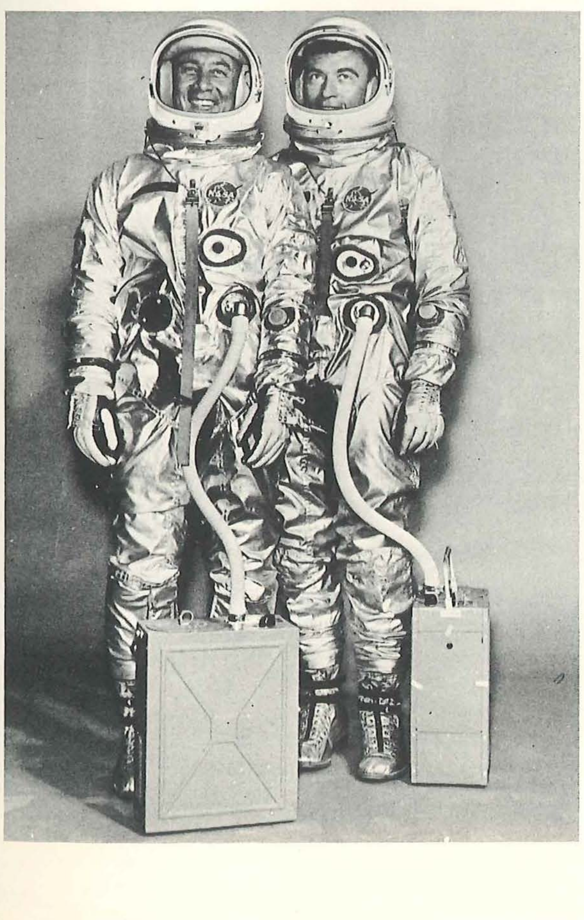
and the moon will be influenced by both bodies, and also by the sun.

What is escape velocity?

To leave the earth on space exploration missions, a spacecraft must overcome the pull of earth's gravity. To do this, a speed of slightly more than seven miles a second, or 25,000 miles an hour, is required. It is known as "escape velocity." It does not mean, however, that the spacecraft is forever free from earth's gravitational influence; only that the vehicle will not be pulled back to the earth's surface even when its power that allows its escape is exhausted.

At a speed lower than that of escape velocity, a vehicle can counterbalance or "cancel out" earth's gravity. For instance, assume that a spacecraft is launched into a horizontal path at an altitude of 300 miles. Since it is above the effects of atmosphere (see page 14), it will continue to move at its original speed. It will be, however, subject to two forces. The first will be centrifugal force which impels all objects away from the center of the earth. (This can be illustrated by noting how you have to lean inward to overcome a bicycle's tendency to lean outward when going around a circle.) The second force will be the downward pull of earth's gravity. (If you throw a ball into the air, it falls to earth because of the pull of gravity.) If, at 300 miles altitude, the original speed is 17,500 miles an hour, the net

Wearing a specially-made space suit and lying down for the take-off as well as for the landing help the astronaut to withstand the high g pressures.



Grissom "seated" in the Gemini procedures trainer, ready for a training session.

Astronauts Virgil Grissom (left) and John Young (right) pose in their space suits designed for the Gemini space flight.

Astronaut See takes a turn on the Astronaut training swing.

effect of these two forces or pulls would be zero. One would counterbalance the other — the spacecraft's path of movement exactly matching the curve of earth. It would remain in that state indefinitely if it does not encounter any other force and continues to move about earth at the same speed and altitude. It would then be in orbit, a satellite of earth. The word "satellite" *(SATT-uh-lyte)* is generally used to mean any object that revolves around a larger body. In this sense, the planets are natural satellites of the sun, and the moon is a satellite of earth.

An orbit, then, is the path in which a body moves relative to a source of gravity. But most satellites, manned or unmanned, do not stay in a circular orbit or at the same distance from earth all the time. Their orbits have the shape of a flattened circle, an ellipse. One end of the ellipse comes closer to the earth than the other. The point closest to earth is called the satellite's "perigee." The point farthest from earth is called the "apogee." The speed required to launch any object into such an orbit is called the "orbital velocity."

What are acceleration and deceleration?

Like the spacecraft, an astronaut must contend with the force of gravity and the laws of celestial mechanics. As we said earlier, the normal pull of

gravity on the surface of earth is one g. When there is a change in this pull of gravity, our bodies feel it. For example, when you are in a car that increases, or accelerates, in speed, you feel yourself being pushed against the seat. When the speed is slowed down (deceleration) during the braking, you are thrown forward. Acceleration will occur when the spacecraft is launched, while deceleration is felt during re-entry.

To leave its launching pad, a spacecraft must reach a speed of at least 17,500 miles an hour to go into an earth orbit and as much as 25,000 miles an hour for an interplanetary or moon journey. These high speeds subject the spaceship's crew members to intense acceleration forces. In Glenn's space flight, his body was under a pressure of 7.7 g's under maximum acceleration and deceleration; this meant that his

Astronaut Trainees White, McDivitt, and Armstrong experience weightless flight, created for brief periods in an Air Force jet transport by nosing the plane first into a steep power dive and then a sharp climb.

In this laboratory device, a system of slings supports most of the weight of the man and allows him to walk and jump under conditions simulating the gravitational effects that exist on the lunar surface. The support system is being used to study the ability of man to perform various tasks on the moon where the force of gravity is only one-sixth of that on earth.

160-pound body weight (under the normal one g-force) was almost 1,232 pounds at these times. Under this increased weight, his body organs, his stomach, his eyes, were squeezed down. His blood became as heavy as mercury or liquid lead. His arms and legs felt like steel bars. If you wish to get a small idea of how Glenn felt, lie down flat on the ground. Ask two of your friends to hold down one of your arms with all their might. Now try to move your arms. Impossible? This is what acceleration and deceleration — sometimes space scientists call it "plus-gravity" — feel like.

Although the crushing effects of the g-forces can cause great discomfort, men can be trained to withstand up to about 15 g's for brief periods of time (see page 11). By wearing space clothing and by lying flat on his back facing the direction of acceleration, an astronaut can overcome the bad effects of even a higher g factor. In most of the planned spacecraft, the astronauts will lie on their backs in especially designed contour couches with their legs in a slightly elevated position. The couch helps them to endure the changing g-forces during acceleration and deceleration.

Is weightlessness a problem in space flights?

After a period of high acceleration and its plus-g forces, the astronaut must next face weightlessness, or zero gravity, when he reaches orbital altitude or escapes from the earth's orbit. An astronaut becomes weightless when the centrifugal force, the outward pull of his spacecraft, equals and thus cancels out the earth's gravitational pull on his body. In other words, while in space, his "weight" drops to zero. Although we call this condition "zero gravity," it should not imply absence of gravity; rather, it means a lack of resistance. The weight of the human body (or any other object on earth) is equal to the force of the earth's gravitational pull on that body or object. We can feel our weight because something is resisting earth's gravitational pull — the ground, or the floor of a building — between our body and the center of the earth's gravity. Without this resistance, we would feel no sensation of weight.

We have all experienced for a moment or two this feeling of lack of weight on roller-coasters when they whip over the top of a short grade after shooting down a long hill. For a split second, you feel your body begin to lighten and you hold on more tightly to the rails as the built-up force and speed of the coaster spring it free momentarily from the normal gravitational pull of the earth. The same feeling, of your stomach being left behind, also hits you briefly in a high-speed elevator when, after it has shot upward, it suddenly brakes to a halt at your floor. But these are only fragmentary hints of the phenomenon, since there are no real situations of weightlessness that can be experienced on earth.

While in space, the spacecraft, weightless itself, cannot push or support against any objects which it contains. These objects in turn become weightless. The slightest movement by an astronaut is multiplied many times

Astronaut drinking orange juice from a plastic squeeze-tube.

because there is no resistance to it. A single vigorous step would be impossible because he would go floating across the cabin. Objects would float while weightless unless fastened down with magnets or other devices. This is a real hazard in a space cabin. When Astronaut Cooper awoke from his first nap during his 34-hour flight, he found his arms "floating" in front of him. Thereafter, to avoid the possibility of touching controls while asleep, he tucked his thumbs under straps on his spacesuit before closing his eyes.

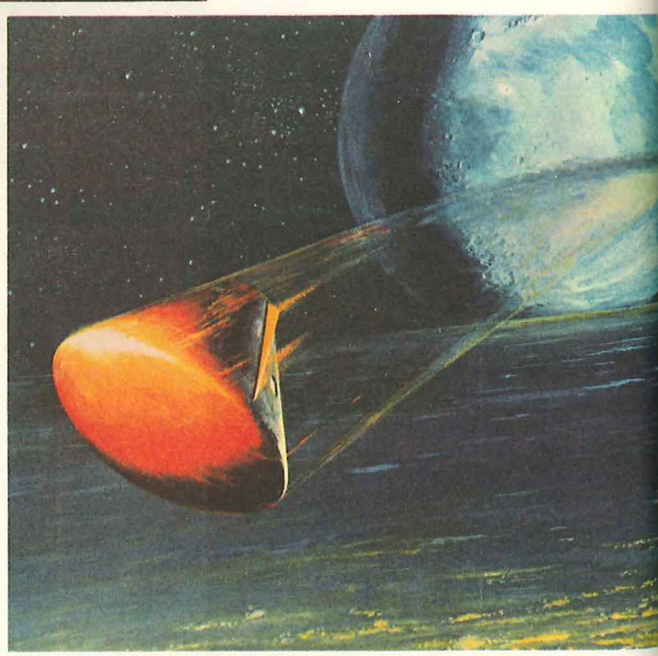
The effects of long periods of weightlessness are, at present, unknown. In our early space flights, weightlessness was no problem; as a matter of fact, Astronaut Schirra, who experienced nine hours of weightless flight, termed it "most pleasant." However, these flights were of rather short duration. On long flights, there is still the question of whether prolonged weightlessness might not bring on disorientation, nausea, or other bad effects. The changes could be so severe that the astronauts would not be able to perform the intricate navigation and control functions required of them.

The answer to the problem may be found in the forthcoming space flights. One possible solution is to provide the spacecraft with an artificial "gravity," so that the astronauts will have at least a portion of their normal earth weight. This artificial gravity may be achieved by some type of mechanical device which would spin or rotate the spacecraft around its axis very slowly, at about one revolution per minute. This rotation can cause a condition which could give the astronauts a feeling of weight.

What effect has weightlessness on eating?

Weightlessness determines the food an astronaut eats and how he eats it. It could be quite a task for an astronaut to eat weightless food and drink a floating blob of weightless water with-

One of the great hazards of manned space flight is the effect of solar radiation (see page 22). This is one of the reasons why, among the many things our astronauts have to study during their preflight training, is the sun. Shown here are Astronauts Walter Cunningham, Alan Bean, William Anders, and Russell Schweickart, and University of Arizona Professor Spencer R. Titley viewing the image of the sun reflected onto a viewing stage by the solar telescope at Kitt's Peak Observatory near Tucson, Arizona.



The artist tried to depict extreme heat, another hazard of space flight (see page 20), which occurs during re-entry of the space capsule (here an Apollo Command Module) into the earth's atmosphere.

out almost drowning himself in it. The cook, the engineer, the flight surgeon, and the expert nutritionists have devised several systems in which the astronaut can feed himself.

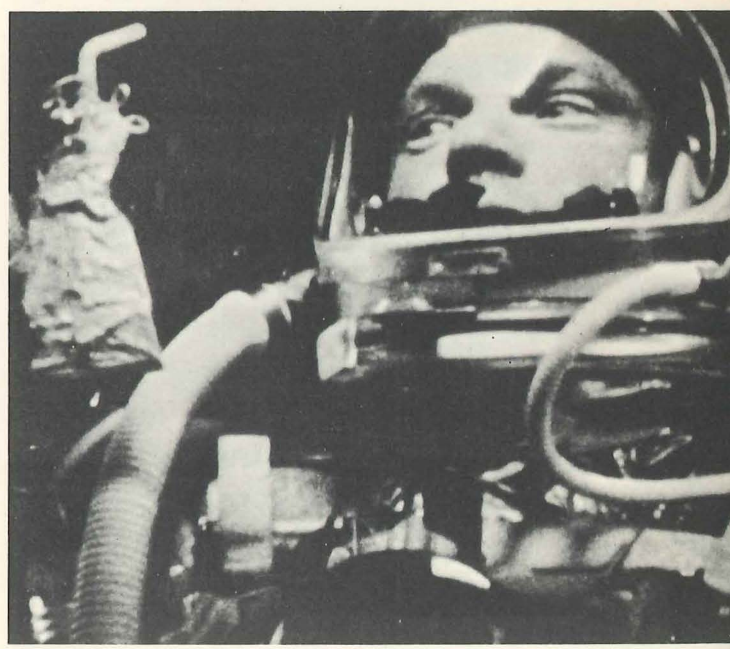
In our space flights up to the present, the method that seems to work best is to use a plastic container which resembles an ordinary toothpaste tube and which is filled with food. By inserting the tip of the tube through the face-plate of his space helmet, the astronaut can feed himself simply by squeezing the tube. Some of the food tubes contain liquids such as water, fruit juices, soup, tea, and coffee. Semi-solid foods such as ham, turkey, beef, vegetables, cheese, and chocolate are also packaged in these squeeze-tubes.

Astronaut Glenn described his eating experiences in a weightless state as follows: "I had one tube of food that I squeezed into my mouth, and this presented no problems swallowing at all. I think the only restriction to food will be that it not be of a crumbly nature, like cookies that have little particles that might break off. You wouldn't be able to get all these back unless you had a butterfly net. Actually, as long as the food is solid, you can hold onto it and get it into your mouth, and from that point on there appears no problem. It's all positive action. Your tongue forces it back into the throat and you swallow normally and it's all positive — a positive displacement machine all the way through."

There is one thing you do an astronaut cannot do because of weightlessness — wash your hands before and after meals. To keep his space suit gloves clean, however, he slips a plastic cover over them.

What food will the astronauts eat while on a long space flight?

Although astronauts on longer-range missions may not be able to sit down to a fancy blue-plate dinner with all the trimmings, at least they will be able to enjoy food that tastes good. The food will be available in purée form to be taken from tubes; others will be in solid form that must be chewed. Some of the solid foods will be dehydrated or freeze fried and will have to be reconstituted with water. A special space water gun is being designed to restore the moisture to dehydrated foods, but in some cases, the moisture required will have to be sup-



A photograph taken by an automatic camera during John Glenn's flight shows a weightless applesauce tube floating free (at the left of the picture) following a snack by the astronaut during his first orbit.

plied by the astronaut's salivary glands. Heated meals will be possible either by using warm water for mixing or by a plug-in heater.

Because food can be a problem on space voyages lasting months or years, scientists are studying the possibilities of "closed recycling systems" whereby plants convert human wastes into edible food. Experiments so far have not resulted in an acceptable diet.

Another possible answer to the food supply problem may be found in plans to grow food within the ship's "atmosphere." Algae, plants with high food value and small bulk, can be grown in artificial cultures and converted into edible forms of food. Experimental systems for accomplishing this have been built in the laboratory and tested. The systems, however, are limited by weight and other factors, and cannot be used until redesigned to reduce the weight while still maintaining successful algae growth. Later in the Space Age, there is a possibility that a spaceship could rendezvous with an orbiting supply station already sent into space. There, it would pick up needed food and fuel and then proceed to its destination.

The astronauts, however, will never be without an emergency food supply. A mixture of powdered milk, hominy grits, cornstarch flour, and dry banana flakes is heated and molded into a structure material like fiberboard. The resulting "food" is strong and light enough to serve as instrument panels or compartment dividers in spacecraft. It holds nails, can be sawed or molded, and lasts indefinitely. For use as emergency food, pieces whittled away with a knife can be soaked in water to make a cereal-like food. One hundred grams will provide 300 to 400 calories.

How will astronauts get their water?

Water is another vital need for every man and astronauts are no exception. For short flights, they will carry water in squeeze-tubes. In the Gemini spacecraft, electrical power is created for the first time through a chemical reaction in fuel cells of hydrogen and oxygen. A by-product of this reaction is a pint of drinking water per kilowatt hour.

For really long flights, a system of recovering, purification, and re-use of body wastes has been designed that would require only 29 gallons of water for four astronauts for one year, the same amount the average American uses in one day. Through this regeneration, or re-use of body wastes, and a purification system, the original 29 gallons of water would be used over and over again by the four astronauts for drinking, food preparation, and sanitation. Without re-use of the water, the four men would require a minimum of 1,800 gallons of water to last them a year. In other words, the astronauts would have a water well in space that never would run dry.

Where does the astronaut get the air he breathes?

Man uses about two pounds of oxygen each day to breathe. This he gets, of course, from the atmosphere. (The atmosphere is a mixture of gases that surrounds the earth. It is composed of oxygen, carbon dioxide, nitro-

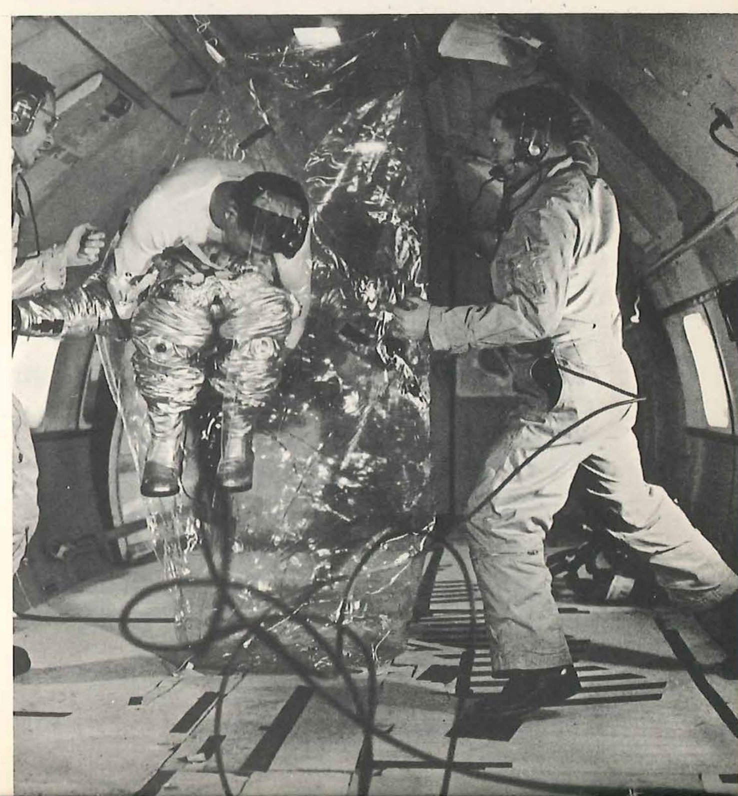
Prototype of the space suit and life-support backpack being developed for Apollo Moon Landing Program. Rubber bellows at the joints of arms, legs, and torso provide greatly increased mobility when the suit is pressurized. The helmet has an airlock feeding device which can be used for eating and drinking in the weightless conditions of space as well as on the moon. The pack supplies oxygen and ventilation, controls temperature and humidity, and removes respiratory and body contaminants inside the suit. It is designed for four-hour expeditions to the moon or in space.

gen, and other gases.) But since there is no atmosphere in space, the astronaut must be provided with air to breathe.

Tanks containing oxygen are built into the spacecraft; a pump forces the oxygen into the cabin, in much the same manner that airliners are "pressurized" so that the passengers can breathe normally at altitudes where outside air is much too "thin" for normal breathing. Should something go wrong with the cabin supply of oxygen, an emergency device immediately starts pumping oxygen from special tanks into the space suit to provide air for breathing.

As he breathes, the astronaut exhales carbon dioxide, which can be poisonous if large amounts are allowed to accumulate. In our present spacecraft, this harmful gas is absorbed and neutralized by chemical canisters installed in both the cabin and the space suit.

The doff-and-don bag tested here is designed to protect Apollo astronauts in depressurization emergencies. Aim of the experiments is to develop a bag in which the astronaut can move around and which can be pressurized even if the spacecraft loses pressurization.



On long missions, the oxygen supply required presents special problems which have been the subject of extensive testing and experimentation by our space scientists. Several cycling devices, which would remove carbon dioxide and produce oxygen, are being tried out, but the one that seems most interesting is based on the same algae that is being considered for food. In growing the algae in the spacecraft, the algae would, as all green plants do, absorb carbon dioxide and water from the air and give off oxygen to the cabin atmosphere. (This process by which all green plants make their own food is called "photosynthesis.")

Why is atmospheric pressure important to the astronauts?

To survive in the near-vacuum of space, the cabin of the spacecraft and the astronaut's space suit must be designed, as nearly as possible, to duplicate the environmental conditions of the surface of the earth to which man is accustomed. This means that the astronaut must be provided with an atmospheric pressure close to that of earth. At sea level, this pressure is 14.7 pounds per square inch. We do not feel atmospheric, or air, pressure, because the pressure is the same from within our body as it is from the outside.

As there is no atmosphere in outer space, there can be no atmospheric pressure. To create it, the same oxygen supply that furnishes the astronaut with air to breathe is used to give the cabin and space suit the required atmospheric pressure. In the Mercury spacecraft, an environment of pure oxygen at a pressure of 5.1 pounds per square inch, a little over a third of normal sea level pressure, was maintained. The same atmospheric conditions hold in the Gemini spacecraft. For insurance against the possibility of a leak and sudden loss of oxygen in the capsule, Gemini astronauts—like the Mercury astronauts—remain in their space suits throughout their flights; separate oxygen supplies are provided for the suits. In the Apollo spacecraft, however, it is planned to provide an atmosphere nearer normal, at a pressure half that of sea level with two-fifths oxygen and three-fifths nitrogen. This will create a condition in the spacecraft which will make it safe for the astronauts to remove their space suits during the long journey to the moon and back.

Why could your blood boil in space?

Most of us have either heard or used the expression, ". . . makes my blood boil." While this is used to express anger, an astronaut's blood could actually boil in space, if there were a loss of the cabin's or space suit's atmospheric pressure.

We know that our blood is mostly water — 92 per cent water, in fact. Water boils at 212° F. at sea level. But as the atmospheric pressure lowers, the lower the temperature becomes at which water will boil. Atmospheric pressure decreases the farther we go up in the atmosphere. If we climb, for instance, to the top of a mountain, the air is thinner and pressure is less than at sea level. At some point, the water will boil at 180° F. instead of 212° F.

If we continue to climb — now, by airplane — to a point about 63,000 feet above the earth's surface, water will boil at 98.6° F. This temperature is most important since it is the same as our bodies. Should we still go higher, water will boil at a very low temperature, much less than 98.6°. Thus, if the astronaut loses atmospheric pressure in space, where water boils at less than 40° F., the heat of the body, 98.6° F., will cause the water in the blood to boil!

How does the astronaut keep comfortable while in space?

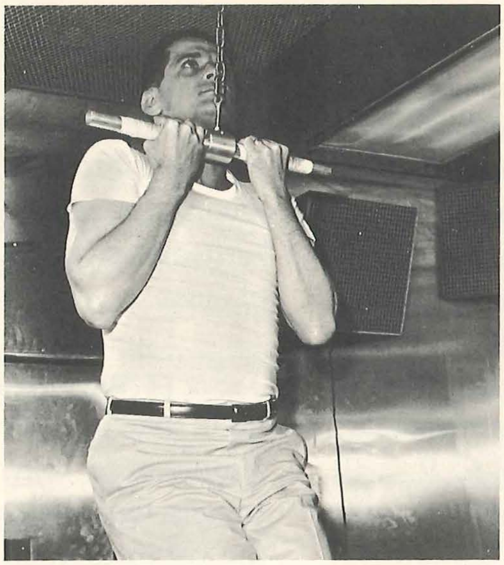
Extreme heat and cold are another hazard of space flight. When the astronaut's spacecraft blasts off and bores upward through the earth's dense atmosphere, the friction of the air against his vehicle, traveling anywhere from 17,500 to 25,000 miles an hour depending upon his mission, can heat its metal outer surfaces to greater than 1,500° F. Do you want to see for yourself how friction can make something hot? Take a piece of metal — a key, for example — and rub it as hard and as fast as possible against the sidewalk. It would not take long at all for the key to become quite hot. The harder you rub, the greater the heat. At 17,500 miles an hour, the spacecraft rubs heavily against the air and produces high temperatures in the metal.

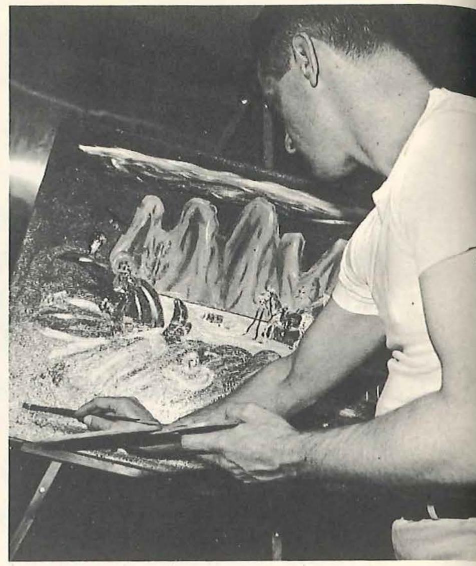
When the astronaut soars into orbit, the sun's rays bakes the spacecraft on the "sunny" side of the journey, while its "shady" side chills in the raw, subzero cold of outer space. When he re-enters the earth's atmosphere for the craft's landing, the friction of the air scorches his spacecraft again with temperatures as high as 3,000° F. Astronaut Cooper stated that during his re-entry into earth's atmosphere, the metal outside of his space capsule turned to a bright orange glow because of heat.

To permit the astronauts to perform their functions in comfort during these temperature extremes in their space travels, the temperature and humidity in the cabin of their spacecraft are carefully controlled by a type of air conditioner called a "heat exchanger." Hot air from the cabin is drawn into this heat exchanger by a fan, cooled by water, and directed back into the cabin. This is the system that kept the Mercury spacecraft comfortable even during the "hot" period when the capsule re-entered the earth's atmosphere and air friction built up enormously high temperatures on the outside of the craft. The Gemini and Apollo spacecraft feature improved models of the heat exchanger. The astronaut's space suit also has its own air-conditioning system similar to the one that cools the cabin.

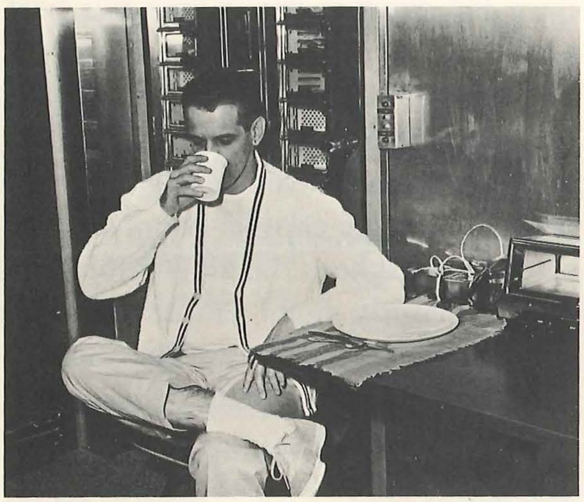
What psychological problems do the astronauts face?

The astronaut's reactions to the absence of the normal earth day-night cycle, the isolation from the familiar world, and the effects of prolonged confinement in a small area can create psychological problems to which he has to adjust properly to fulfill his mission. The confinement especially can result in a kind of mental fatigue which could impair judgment and alertness.





To study the psychological effects of the astronaut's isolation from the familiar world, experiments are conducted which simulate some of the problems. The photo sequence we show here was taken during an experiment at the University of Maryland. Whilden P. Breen, Jr., entered a specially-constructed isolation chamber on November 17, 1962, and was released on April 17, 1963. One of his many projects during his confinement was to paint (photo right). When the "WEIGHT" light was lit on the command panel, he was required to place his weight on an electronic weighing device (photo left).



Mr. Breen could select from either side of the vending-type machine shown in the background (which made either hot or cold food available) a predetermined number of items of food which were stored in a predetermined quantity.

To overcome space fatigue, medical men are setting up exercise programs for astronauts to follow while in flight. Because of limited space and weightlessness, the astronaut cannot work out by doing calisthenics. His exercises are simple, but they are helpful muscle exercises such as interlocking the fingers while trying to pull them apart, or grasping the arms of his seat to hold himself firmly down while at the same time trying, with his legs, to push himself up.

What hazards do the astronauts face after leaving earth's orbit?

As the astronauts get farther and farther from earth or leave its orbit, the hazards they face increase greatly. One of the first problems is radiation. We all are familiar with the severe burn that the sun's rays can give us. But, these ultraviolet rays that cause sunburn are only one form of solar radiation. On earth, the atmosphere gives life-saving protection from solar radiation. But in space where no shielding atmosphere protects the traveler from ultraviolet rays, X-rays, and other radiation, the dangers are in abundance. The solar radiation seems to be the strongest in two zones roughly 2,400 miles and 10,000 miles from the earth's surface. They are separated by a region called the "slot," where radiation is at a minimum.

The two radiation zones were named the Van Allen belt in honor of their discoverer, Dr. James A. Van Allen.

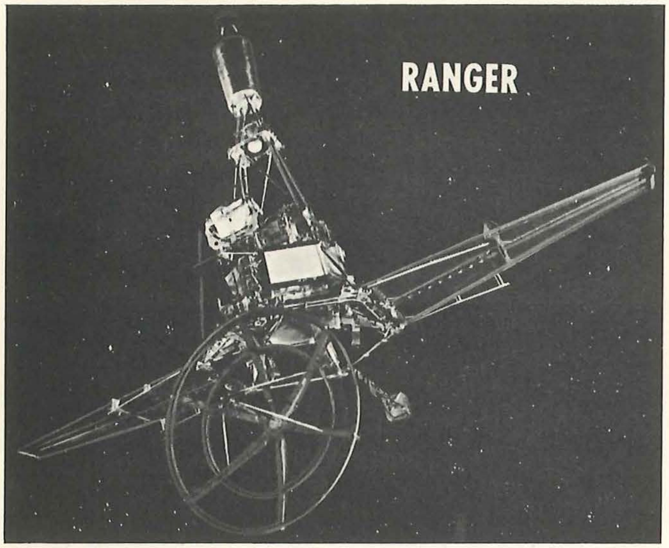
In the Gemini flight — like in the Mercury — radiation is only a minor problem since earth-orbital missions are executed well below the Van Allen belts. But the Apollo astronauts will have to go through them on their trip to the moon and back. However, they will be exposed to them for a total of only a few hours and protection will be provided by special shielding of the spacecraft and by a special space suit designed for this purpose.

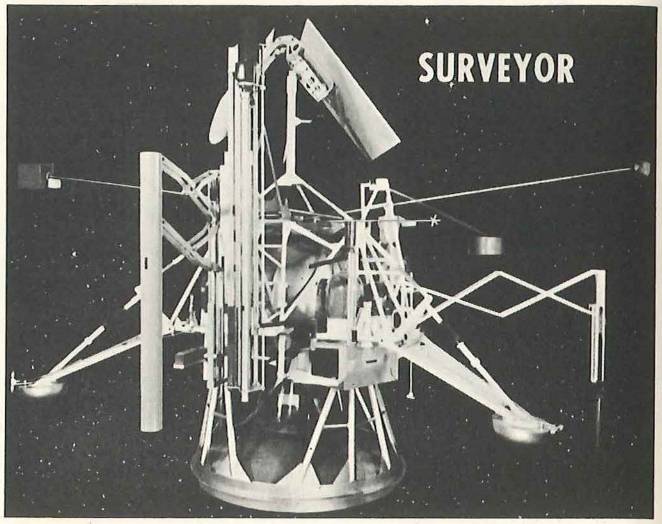
What are solar flares?

The Van Allen belt, however, is not the only radiation hazard. As we know, the sun throws off many billions of tiny particles called "cosmic rays" which travel hundreds of millions of miles into space. While these rays are being given off constantly, there are times when highly increased amounts of cosmic rays emanate from the sun. Such eruptions are called "solar flares" or "sun storms." While solar flares occur frequently, the increase in cosmic rays is not always alarming and protection for the astronauts can be built into the spacecraft. Occasionally, however, there is a major solar flare which sends out radiation so intense that the weight of shielding material necessary for protection would be prohibitive. The only solution, at present, to this problem seems to be some method of being able to predict the build-up of a giant flare and then postponing the space voyage. In the past 10 years, only seven giant solar flares have been observed; an unexpected one could be disastrous for a lunar trip.

Another peril to astronauts comes from meteoroids. Millions of these tiny bits of rock-like materials, each traveling at speeds better than 100,000 miles an hour, will hit the spacecraft during its trip. Most of them are only about the size of a grain of sand. Shielding around the cabin should keep them out, but any meteoroid about the size of a pebble could easily blast its way through any spacecraft aloft. If a piece should hit an astronaut, destroy a vital part of the craft, or explode on contact with the capsule's oxygen, real trouble would result. Scientists figure, however, that there is only about one chance in ten thousand that a spacecraft in flight from the earth to the moon would en-

Perhaps the greatest hazard the Apollo astronauts face will be found on the moon itself.



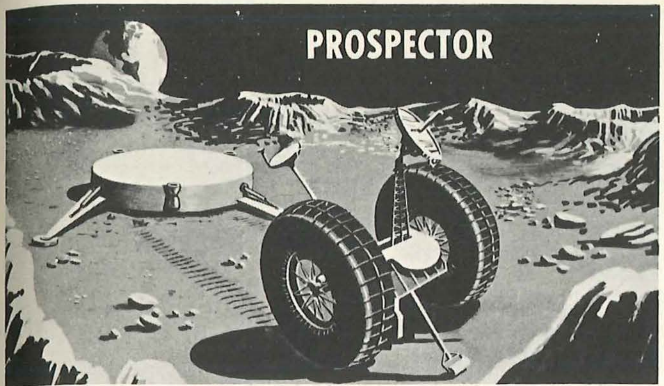


counter a meteoroid large enough to penetrate the shielding of the Apollo vehicle.

Perhaps the greatest hazards the Apollo astronauts face will be found on the moon itself. If the moon were just a small replica of earth, manned exploration of this natural satellite would be a relatively simple problem. But the moon seems to be a forbidding and hostile place for those who violate its lonely surface. For many years, scientists have studied the moon, its temperatures, its lack of atmosphere, its type of surface, its motions, etc. There are many conflicting ideas about — and, also, numerous points of agreement on —what the astronauts may expect when they reach the moon. Much more, of course, will be learned from unmanned moon probes. (A probe is any unmanned instrumented vehicle moving through space, or landing on another celestial body to obtain information about the specific environment.) But now that manned lunar exploration is in the advanced planning stages, scientists are studying how the strange environment of the moon may affect its earthly visitors and what experiences may await the astronauts when they leave the hatch of their lunar excursion module and set foot on the moon for the first time.

What will "moonsteps" be like?

Those first steps taken by the astronauts will be leaping ones. Because the moon's gravitational pull is only one-sixth that of earth, a 180-pound astronaut, or "lunarnaut," as he would be called while on the moon, will weigh but 30 pounds. His new weight will affect his walking and any pushing or pulling he does. "Earthmen," aware of this phenomenon, already are trying out their "moon legs" in a science laboratory. By means of a harness, helium balloons lift all but one-sixth of a man's weight, simulating the reduction in weight he will experience on the moon. Under these conditions, walking or the use of hand tools becomes extremely difficult.



Ranger, Surveyor, and Prospector are three unmanned probes which have to explore the moon before the landing of astronauts will be attempted. Ranger is the type of probe which, with a payload of 6 television cameras, hit a bull's-eye on July 31, 1964. After being launched from Cape Kennedy on July 28, 1964, the vehicle made a 228,600-mile voyage and enabled the cameras to send back to earth thousands of pictures of the moon from close by before it crashed on its collision course at 58,000 m.p.h. near the "Sea of Clouds."

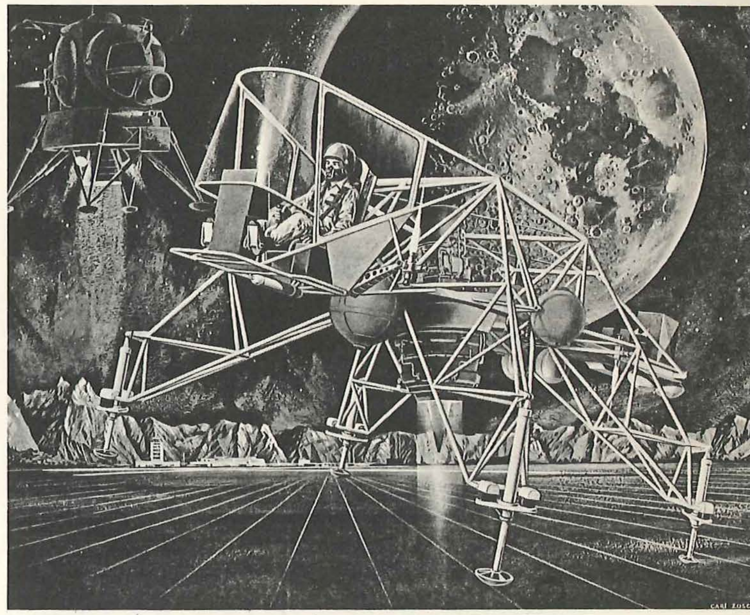
Man must learn new ways to do even the simplest tasks on the moon.

Have you figured out by now why Astronaut Shepard wants to play golf on the moon? Because of the lower gravitational pull and lack of atmosphere, he could drive golf balls for miles without any difficulty.

How will astronauts communicate while on the moon?

The moon explorers, having taken their first bounding "moonsteps," can only talk to each other by radio. Even if they could remove their space helmets, they could not hear each other, for there is not enough air or atmosphere to carry sound waves. Complete silence reigns on the moon, and communication is possible only by radio, provided the astronauts are not too far from each other. Because of the lack of atmosphere above the moon's surface, radio waves can only be sent on a "line of sight." This means that radio can only be used when the two parties can see each other.

Until more complicated communication systems are set up, lunarnauts wandering beyond the horizon might keep in touch with their moon "home base" by setting off small explosive charges. These explosions, of course, could not be heard, but their vibrations would register on portable seismographs so that their fellow astronauts would know their approximate locations.



Artist's concept of a lunar landing research vehicle. The free flight test device will be capable of taking off and landing under its own power, attaining an altitude of 4,000 feet, hovering and horizontal flight. The vehicle will be used to simulate and investigate on earth the problems that may be encountered in lunar landing, about which scientists can only guess.

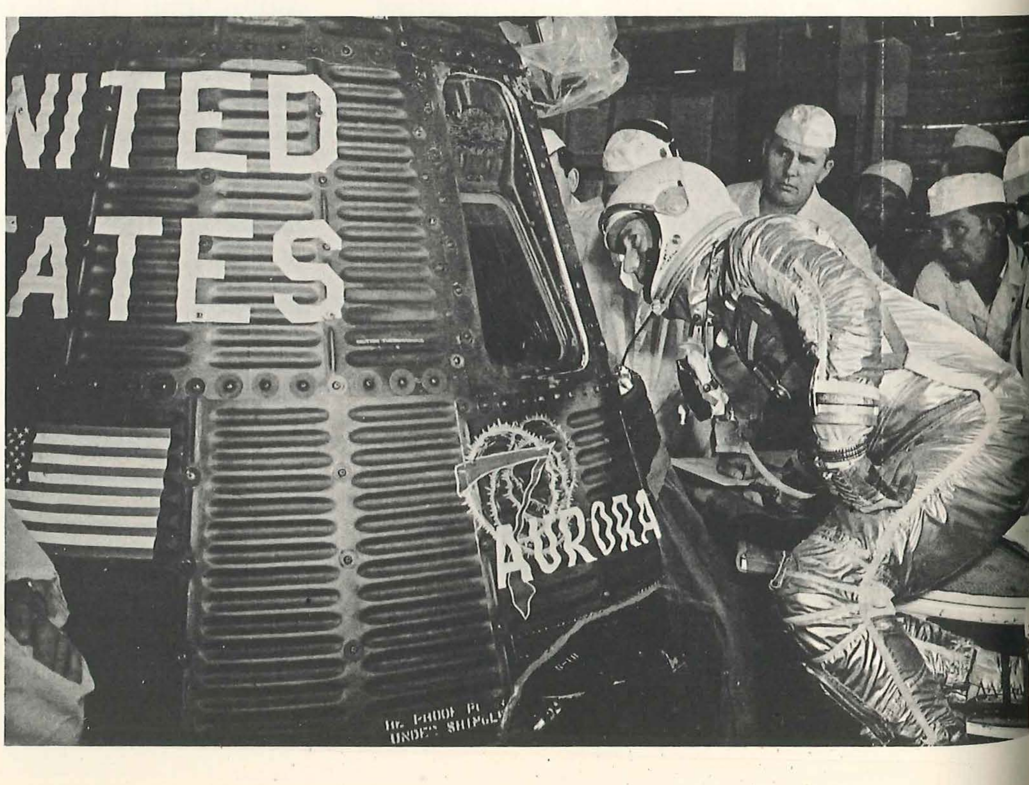
Travel on the moon also presents problems. Because of the lower gravity, any land vehicle, such as cars and trucks, have to be especially designed. While many ideas are on the drawing-boards of designers, very few lunar vehicles will be made until after the first astronauts have landed there and can

man's greatest technical triumph, as he once again proves his ability to dominate his environment no matter how hostile it may be.

Why does a man volunteer to be an astronaut?

With all the danger involved in a space flight, why do men volunteer to be astronauts? Astronaut Carpenter gave his answer in three terse sentences: "It is a chance to serve the country in a very noble cause. It certainly is a chance to pioneer on a very grand scale. I am very happy and proud to have been given the opportunity." Astronaut Schirra gave a still shorter answer when he said: "I was proud and happy to help out my country. I guess there was also a spirit of pioneering and adventure involved."

Possibly, one of the noblest summaries of why a man wants to be an astronaut can be found in the following prayer recorded by Astronaut Cooper during the 16th orbit of his 22-orbit mission: "I must take this time to say a little prayer for all the people, including myself, who are involved in this operation. I want to thank You especially for letting me fly on this flight. Thank You for the privilege of being able to be in this position, to be in this wondrous place, seeing all these startling wonderful things that You have created. Help guide and direct all of us that we may shape our lives to be much better Christians. So that we help one another and work with one another rather than fighting and bickering. Help us to complete this mission successfully. Help us in future space endeavors to show the world that democracy really can compete and still is able to do things in a big way. And are able to do research, development, and conduct new scientific and technical programs. Be with all our families. Give us guidance and encouragement and let them know that everything will be okay. We ask in Thy name. Amen."



Astronaut Scott Carpenter, whose reason for volunteering for his "job" is quoted above, looks inside *Aurora 7* spacecraft prior to boarding. NASA technicians watch Carpenter prepare for his programmed three-orbit mission within the Mercury Program.

The Astronauts' Training

Astronaut Virgil I. Grissom achieves stability in the MASTIF trainer.

Because of the many risks of space flight, astronauts are subjected to probably the most rigorous training program ever devised for man. The Project Mercury space flight team trained for three years. Projects Gemini and Apollo require 18 months of training. (The reduction in training time resulted from experience gained in Project Mercury.)

The astronauts spend a great deal of time in "school." Their classroom work includes courses in navigation, aerodynamics, physics, meteorology, computer theory, astronomy, communications, rocket engines, celestial mechanics, and other space subjects. They also take field trips to the various manufacturers involved in the NASA program. On these trips, the astronauts learn the details of the construction of the vehicles and rockets that will carry them into space. By the way, 9,000 different private firms worked to make Glenn's first Mercury spacecraft flight possible.

How do the astronauts learn to adjust to varying g-forces?

To train the astronauts in conditions that approximate those they might experience on space flights, many techniques and devices are employed. For example,

the one training device which, more than any other, "punishes" the astronauts is known as a "centrifuge" or the "big wheel." This consists of a pill-shaped gondola mounted at the end of a long steel boom or pole. The gondola and boom are driven by a very powerful electric motor capable of generating enormous speeds. The astronaut — wearing his helmet or, for the more strenuous rides, his space suit — is strapped down to a couch in the gondola. Electrodes and a respiration gauge are taped to his body so that continuous records of heart rate and respiration may be kept during the run.

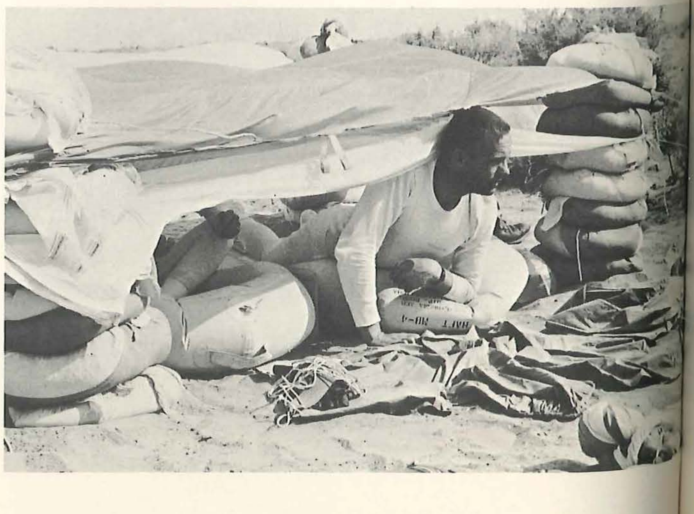
When the astronaut gives a signal, the boom starts to move in a circle. As it whirls around faster and faster, the g-forces increase rapidly, as they do during actual space flight. Actually this whirling boom creates the same kind of g-forces encountered when the rocket accelerates from its launching pad, or when the spacecraft slams back into the atmosphere during deceleration.

Inside the gondola, there are controls similar to those in the cabin of a real spacecraft. During his ride in the centrifuge, the astronaut tries to do the things he would do if he were "flying" his spacecraft — operate the controls, read his instruments, and speak into his microphone. While he is doing these jobs, his body is being pushed against the couch at forces as great as 15 g's. (Remember that a 160-pound astronaut, for example, when under a force of 15 g's, weighs 15 times as much as he would normally — or 2,400 pounds.) While this is a most painful experience, the astronaut knows that he has successfully "flown" under the stress of higher g-forces than he is likely to encounter in an actual space mission.

What is a flight simulator?

As it is impossible to make practice space flights in space, the astronauts do the next best thing. They use machines cleverly built to reproduce the conditions of space flight. These devices, called "simulators," were first developed to help train airplane pilots in World War II, and the idea has proven most successful for the early astronauts.

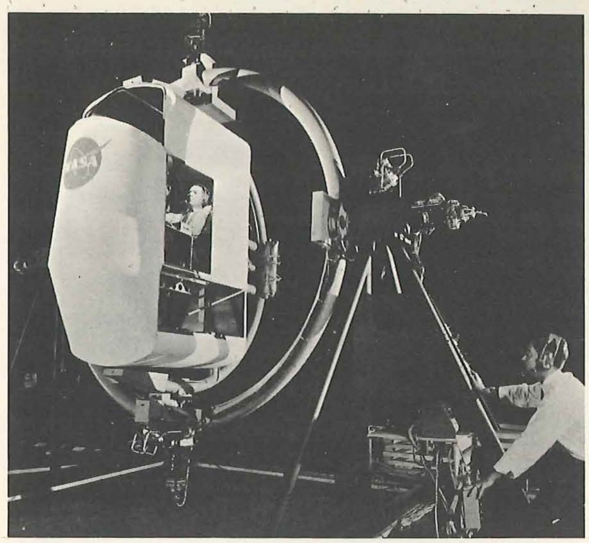
There are several types of simulators, but one of the most interesting and important ones is called "MASTIF" (Multiple Axis Space Test Inertia Facility). This huge machine consists of three frameworks set one inside the other; the astronaut is strapped to a couch in the middle of these frameworks. Each one of the three frameworks produces a different type of tumbling motion — up and down, right and left, and front



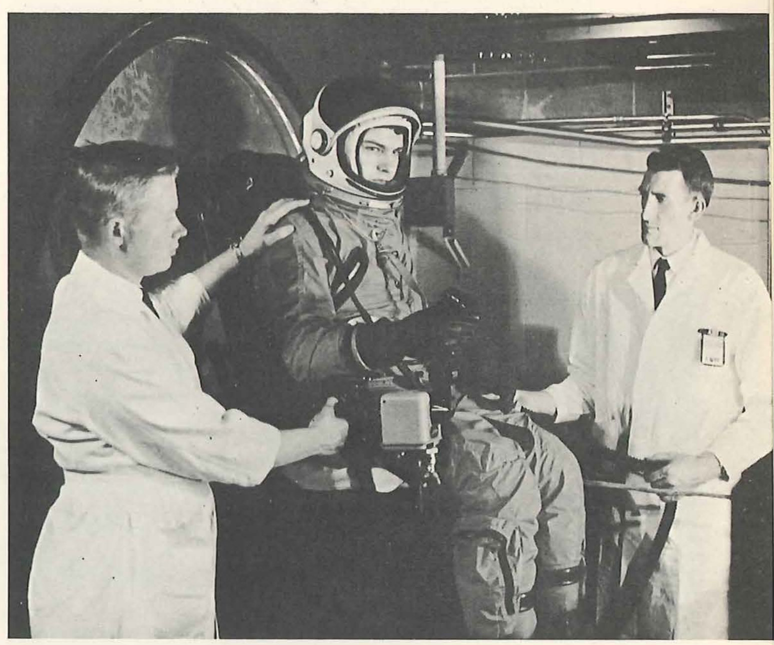
Astronaut Armstrong peers from a makeshift tent during the three-day desert survival training course.

and back. The astronaut can be spun in only one direction, or he can be spun in three directions at once. While the former seldom gives him any trouble, rotating in three directions usually does. He has to fight to focus his eyes on the control panel in front of him, he feels sick, and a cold sweat pops out on his brow. The object of the MASTIF is to bring the device to a stable condition and then bring it to a smooth stop. The astronaut emerges a little weak and wobbly from his ordeal, but he has the confidence that, no matter how much his spacecraft is tumbled about in space, he will be able to control it.

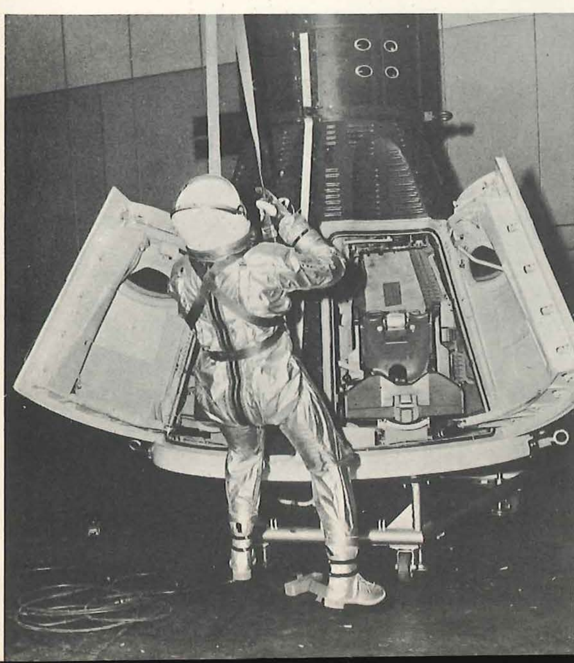
There are less violent simulators used by the astronauts. One of these is called the "full-mission simulator," in which an astronaut, under the supervision of an instructor, may practice all maneuvers for launch, flight into orbit, in orbit operations, re-entry, and recovery at a selected landing site. From the cabin of the simulator, which is an exact reproduction of the one in real spacecraft, the astronaut can see the earth, moon, sun, sky, and stars just as he would while orbiting the earth. Also, with the astronaut inside the simulator, the in-



This simulator is used to help determine human ability to control a lunar launch vehicle during take-off from the moon for rendezvous with a lunar satellite in orbit prior to the return trip to earth. The simulator is designed for operation inside an artificial planetarium, where a star field will be projected against the ceiling during the "flight."



Multi-stress chamber is used to check behavior pattern of space pilots under the conditions of space flight. The pilot is asked to perform piloting and navigating functions in a closed chamber while being blasted with rocket noise. Heat that surges up to 400° F. along the cabin wall, random vibrations, loss of cabin pressure, and other attention-diverting annoyances are created.



An astronaut is lifted out of a Gemini spacecraft in a simulated helicopter recovery maneuver.

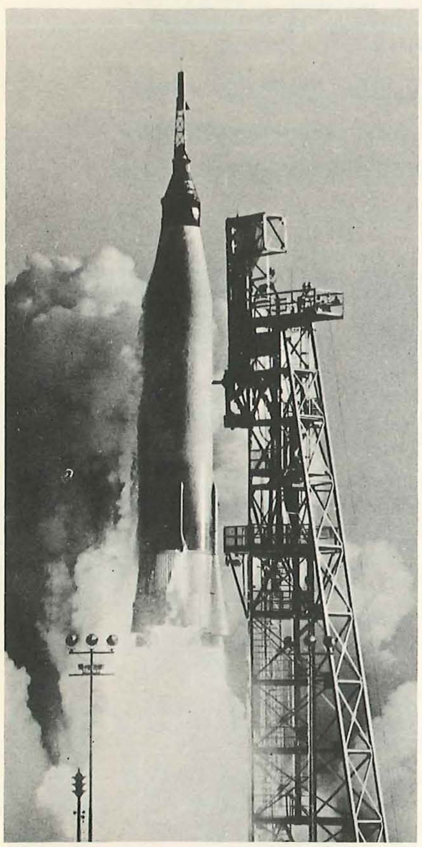
The United States Manned Space-Flight Program

Up to now, we have concerned ourself mainly with the astronaut as a man and the problems he faces as a man. Let us now take a look at the spacecraft that have carried, and will carry, astronauts into space and see the part that they will play in the adventure.

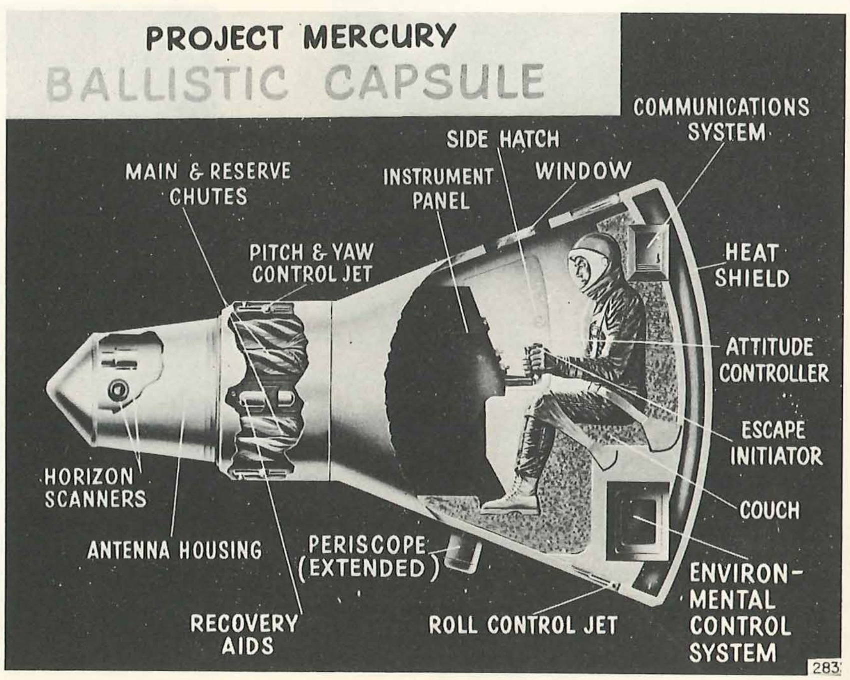
What was the Mercury spacecraft like?

As was stated earlier, all of the first astronauts went into space in Mercury spacecraft or capsules. Compared with the planned spacecraft of the future, the Mercury capsule and its operation could be said to be the "Model T" of the Space Age, yet it contained the basic systems for human survival and it proved that space flight was possible — just as the "Model T" proved that mass production of automobiles was possible. Named for the messenger of the gods in Greek mythology, the Mercury spacecraft had the general appearance of a big bell. At the base, it was six feet across. From this base, the craft tapered nine feet to the top. On the top of the capsule was the escape tower, some 15 feet high, giving the spaceship an over-all height of about 24 feet.

The escape tower was a completely automatic safety system devised to give the astronaut full protection at the time of greatest danger — at blast-off and for the first few succeeding seconds of powered flight. The escape tower had its own powerful rockets, which could lift the capsule off the launching rocket. It could lift the capsule, not straight up,



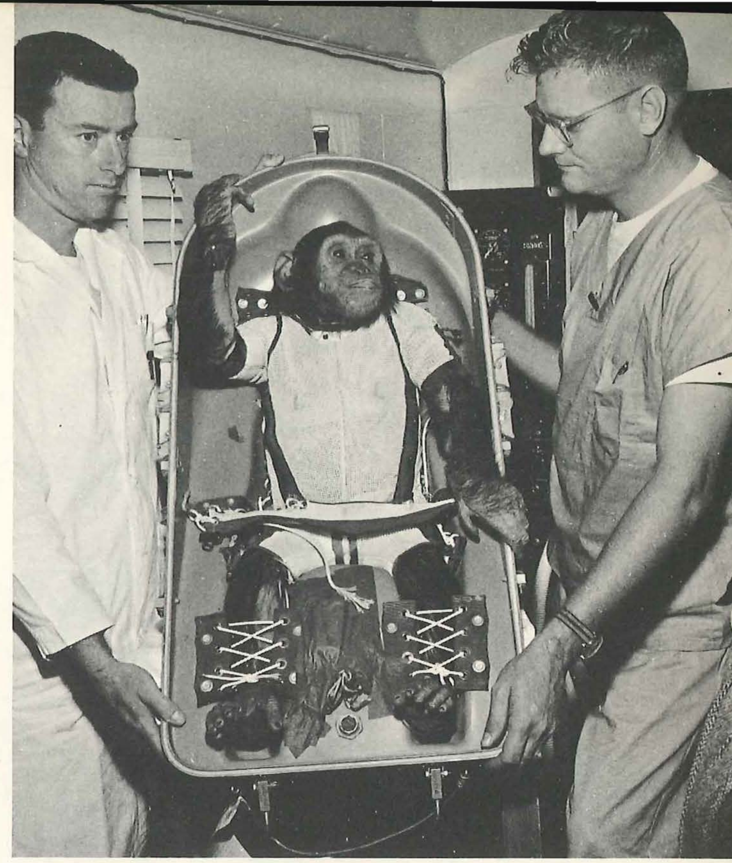
The *Sigma 7* spacecraft, Astronaut Schirra aboard, is successfully launched atop an Atlas D launch vehicle.



but slightly to one side so that it would clear the malfunctioning launching rocket. The capsule could come to earth by means of a parachute. Fortunately, the escape tower never had to be used by the astronauts. The Mercury capsule was launched into space with an Atlas rocket as booster.

Inside the one-man Mercury spacecraft, there was a couch that was shaped to fit exactly the contours of the astronaut's body. This couch helped him endure the great pressures of launch and of re-entry into earth's atmosphere. Once in space, the astronaut had two ways he could see out of his capsule. In the wall of the craft, near his head, there was a window. Protruding from the capsule, near his feet, was a periscope. By looking at a view screen on the control panel, he could see through the periscope.

Indicators on the control panel flashed red if any of the important mechanisms were failing to do their job. A handle was located by each light so that the astronaut could correct failure. Also packed into the spacecraft were seven miles of electrical wiring, hundreds of instruments, switches, radios, lights, and electronic systems to assure proper operation and timing. Behind every vital part was at least one alternate system that could have been readily substituted for it in case of failure of the original one. Nearly every operation could be conducted automatically by radio from earth, or by the astronaut with manual controls. He also had two separate radio systems through which he could talk to ground personnel, often fellow astronauts.



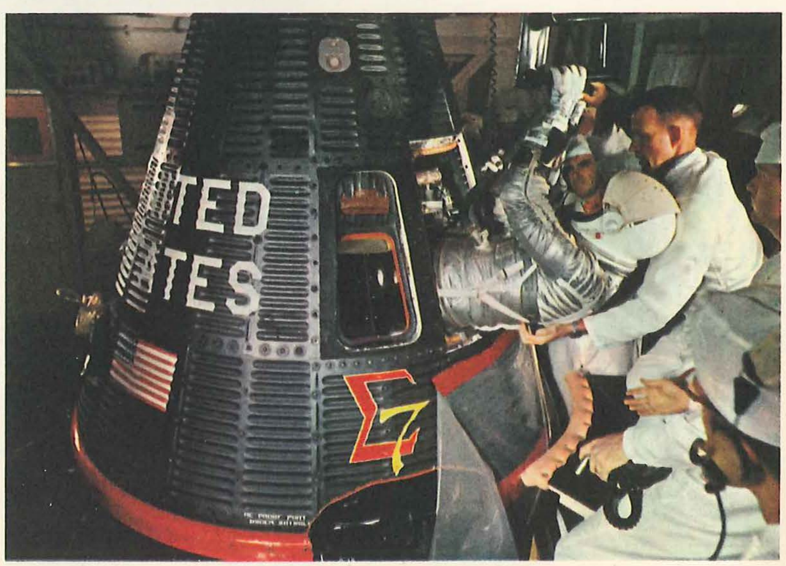
One of the chimpanzees, specially trained for the Mercury Redstone 2 flight, is shown here in the couch in which the monkey rode during the 16-minute ballistic flight from Cape Kennedy in 1961. Scheduled by Program Mercury to provide tests for the spacecrafts' environmental control and recovery systems, the tests preceded manned space flights.

How did the Mercury astronaut get back to earth?

Once the Atlas booster got the spacecraft into space, it separated from the capsule and fell back into the earth's atmosphere, where it burned up. The spacecraft, however, sped along in an elliptical orbit at about 17,500 miles per hour at altitudes ranging from about 100 to approximately 160 miles. In each 90-minute orbit, the spacecraft flew 27,000 miles. Near the end of final orbit, the astronaut was told by ground controllers to prepare for re-entry into the earth's atmosphere. Either automatically or under astronaut control, the capsule was positioned for this critical maneuver. Three small retro-

Inside NASA Mercury Control Center, Cape Kennedy, Fla. The large board indicates the then-planned and later-accomplished orbital flight path of Astronaut Schirra.

Just having completed the first suborbital flight of Project Mercury, Astronaut Alan B. Shephard (outside his spacecraft) and the capsule are picked up by a helicopter of the Project Mercury recovery team and flown to the U. S. Navy Carrier *Champlain* (May 5, 1961).



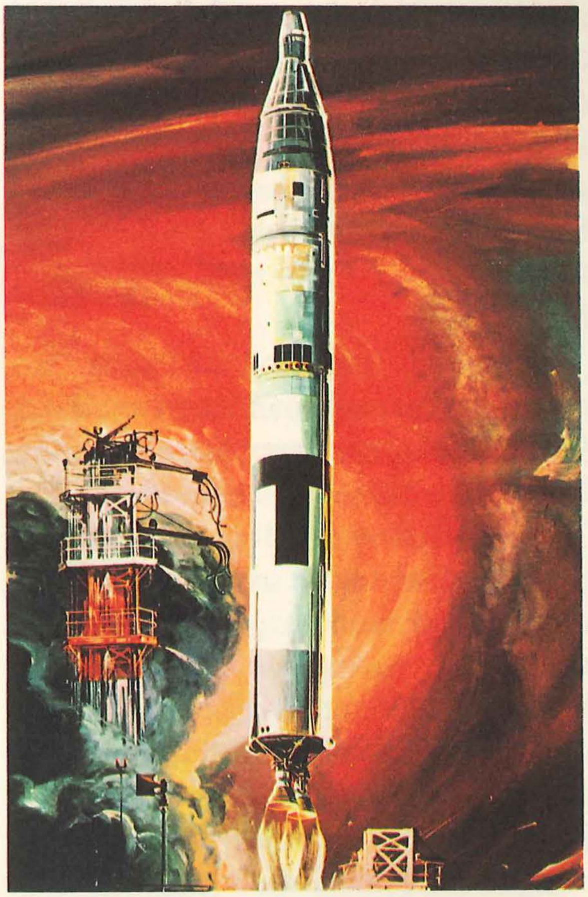
Astronaut Cooper assists Astronaut Shirra into *Sigma 7* spacecraft which was launched on October 3, 1962, at 7:15 A.M. from Cape Kennedy by an Atlas D rocket into earth orbit. Six orbits were achieved before it landed off Midway Island in the Pacific.

rockets, facing forward, were fired to slow the spacecraft for return to earth.

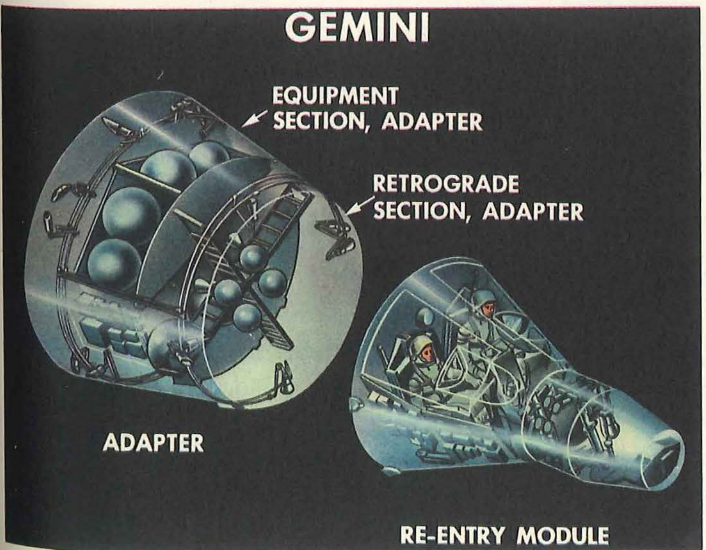
As the spacecraft dropped into the atmosphere like a meteor, the heat on its front end reached temperatures of about 3,000° F., but was dissipated by melting, evaporation, and charring of the surface of special protective heat shield. At about 20,000 feet, a 6-foot-diameter parachute called a "drogue" was released to slow and stabilize the craft. At about 10,000 feet, the 63-foot diameter main parachute is deployed. United States Navy vessels were waiting in the water recovery area. A water landing was chosen for the return of the Mercury spacecraft because of the vastness of the water areas available and because the capsule struck the water at a speed of about 30 feet per second. While this speed was fast enough to raise a tremendous splash, the water had enough "give" to prevent the astronaut from being hurt by the impact.

What does the Gemini spacecraft look like?

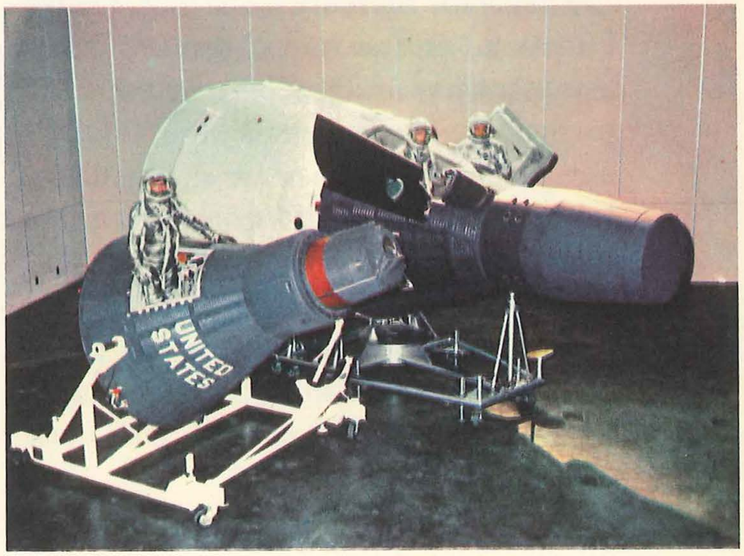
The two-man Gemini spacecraft, aptly named for the constellation Gemini with its twin stars, Castor and Pollux, resembles the Mercury spacecraft externally, but is one and one-half feet wider at the base and lengthened proportionately. It has about 50 per cent more cabin space than Mercury and weighs about 7,000 pounds. Therefore, it requires a more



The two-manned spacecraft Gemini, weighing more than 3 tons, placed in earth orbit by a 430,000-pound-thrust Titan II booster (artist's concept).



Mercury (left) and Gemini spacecraft side by side.



powerful launching rocket or booster, a Titan II rather than the Atlas. The 90-foot Titan II has a thrusting power of 430,000 feet. Also, the Titan II's are simpler than the Atlases, which means a shorter countdown after the astronauts have manned their spacecraft. About the Gemini flights, Astronaut Grissom has said, "We hope to kick the tires, get in, and go without those long hours on the launching pad." Remember that Astronaut Glenn had to wait for over three and one-half hours for blast-off.

Because of the need for more "leg room" for its two-man crew, much of Gemini's necessary supplies are housed in two sections or modules called "adapters," that fit between the top of the launching rocket and the blunt end of the main space capsule. The inner adapter, or retrograde module, holds the re-entry or retro-rockets; the outer one, or equipment module, contains the control-system fuel. The astronauts jettison (uncouple or discard) the equipment module during preparation for return to earth. Then, they jettison the retrograde module just before reentry to lighten the spacecraft's travel in earth's atmosphere.

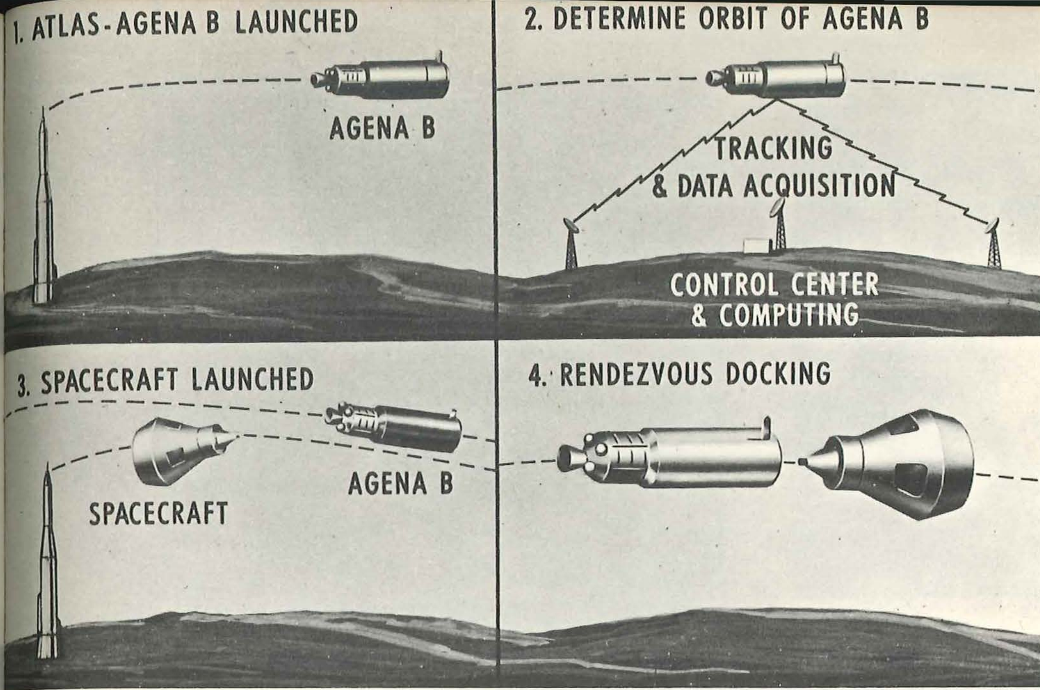
Unlike the Mercury spacecraft, Gemini has no escape tower. Instead, each astronaut has an ejection seat (similar to that used in a fighter aircraft) for escape during launch or for emergencies in the recovery phase. Roll-out couches and hinged doors make it easy for the astronauts to enter and exit from the craft. Two windshields, one for each astronaut, are used in place of the single porthole of Mercury.

How does the Gemini spacecraft land?

In place of the familiar drogue recovery parachute that safely brought the Mercury spacecraft down into water, Gemini rides back to earth under a "Rogallo" wing, a newly developed, steerable, sail-like parachute. In other words, the astronauts are able to maneuver the wing, or paraglider, by adjusting the tensions in the shroud lines. Three skids (ski-like devices) are lowered before touchdown from the capsule, and Gemini slides in for a landing on the ground at a speed of about 45 miles per hour. (For illustrations, see pages 40-41.)

How will orbital rendezvous be accomplished?

A basic objective of Project Gemini is to study the astronaut's capacity to remain in space for periods lasting up to two weeks or more. In addition, Gemini spacecraft is being used, in conjunction with unmanned satellites, to develop techniques for the rendezvous and joining together of two spacecraft in orbit. First, a specially designed space vehicle called Agena is launched into a near-circular earth orbit. Ground stations track Agena by radio and determine the best time to launch Gemini. Later, a Titan II rocket propels Gemini into an elongated orbit with an altitude generally lower than that of Agena, but with an apogee (highest altitude) the same as that of the Agena orbit. Because its altitude is lower, Gemini can circle the earth more quickly than Agena and gradually overtake it. When the two are most favorably located in



One of the basic objectives of Project Gemini is "Operation Rendezvous."

relation to each other, a Gemini tail rocket is fired to increase its speed and to place the spacecraft into a circular orbit almost identical with that of Agena.

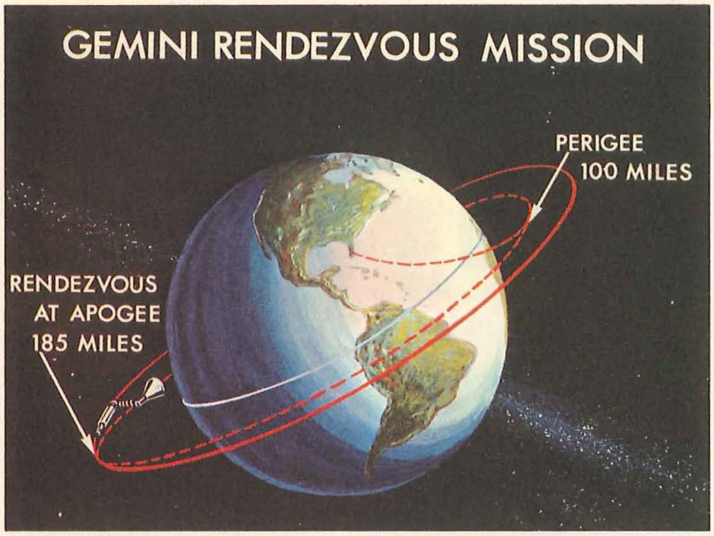
As soon as Gemini's radar picks up Agena on its screen, the so-called closing phase of rendezvous begins. Radar information is fed into Gemini's computer which tells the astronauts which navigating rockets to fire and when and how long they must operate them to keep the craft stabilized and in a position to close in on Agena. When the two craft are about 20 miles apart, the astronauts are expected to sight Agena and supplement radar information with visual observation. A high-intensity flashing light on Agena helps the astronauts keep their target in sight. By the end of the closing phase, Gemini and Agena should be 10 to 100 feet apart and traveling in the same orbit.

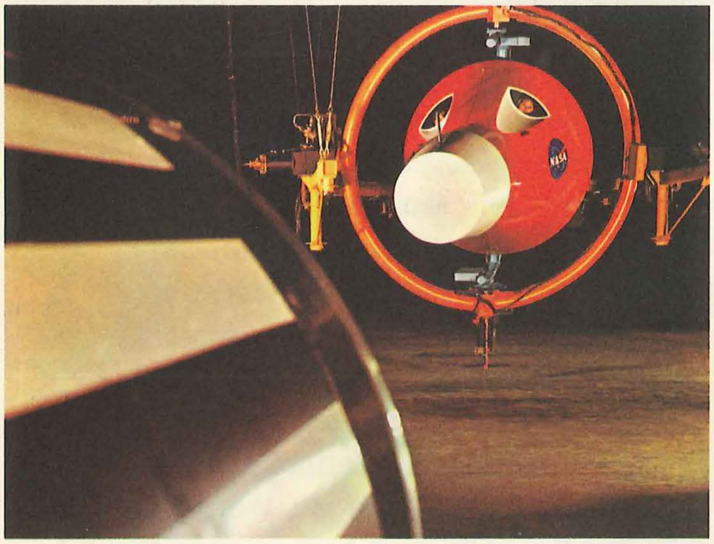
The final phase of rendezvous is docking, the link-up of the two vehicles. In this phase, much of the timing, computing, and decision requirements are within the capability of man. Using visual observation, the astronauts must carefully maneuver Gemini into contact with Agena. They are aided by an aiming bar on the Gemini spacecraft and a notch in Agena's receiving cone.

As they near their target, the astronauts must reduce the relative velocities between the two craft to less than 1½ miles per hour although both are whirling around the earth at about 17,500 miles per hour. Then, they must gingerly nudge the nose into the slot. Coupling or docking is automatic; the astronauts can use Agena's propulsion system, as well as Gemini's, for any further orbital maneuvers. Before the spacecraft lands, Agena must be jettisoned to lighten Gemini's weight for reentry.

Can Gemini astronauts step out into space?

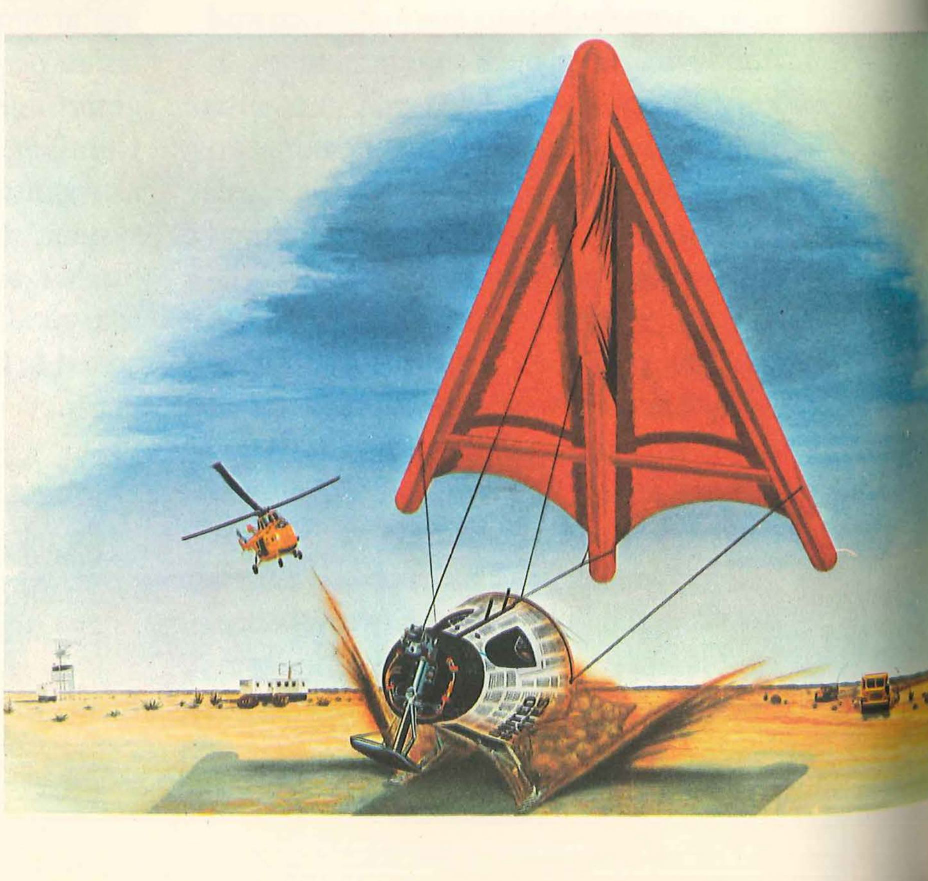
During advanced stages of the Gemini program, its pressure-suited crew may open the hatches and emerge from the spacecraft while in orbit.



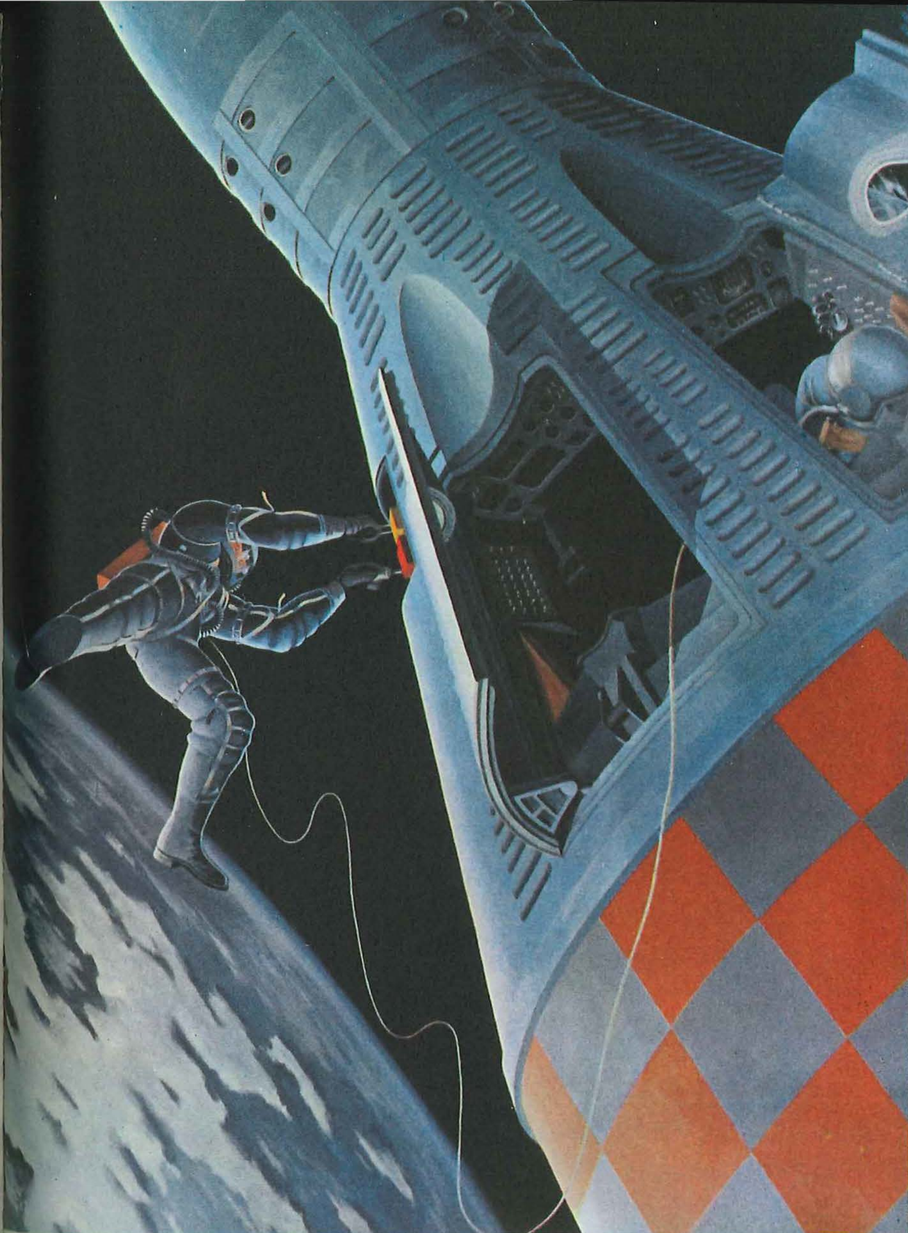


The two-man Gemini spacecraft maneuvers into position for docking with the Agena B.

Ingenious devices like the rendezvous docking simulator shown here are being developed by NASA scientists to explore under controlled laboratory conditions many complex aspects of space flight. The facility will enable scientists to determine man's ability to complete a rendezvous in earth or lunar orbit. The scale model of the Gemini spacecraft can perform like the real vehicle and operated properly, it can be brought into gentle, final contact with a target vehicle. The simulator spacecraft and the target hang on cables from an overhead track.



The paraglider ("Rogallo" wing) has landed the Gemini capsule — the skids are out. Before coming to a complete stop, the wing will be ejected.



Artist's concept of the Gemini spacecraft in earth orbit. One astronaut is shown outside the spacecraft, suit inflated, to do repair work on the capsule.

In simulated weightlessness, an astronaut repairs his ship with one of the tools designed to offset its effects.

Moreover, they may push themselves from the craft, and appear to float in space as they speed around the earth at about 18,000 miles an hour. This operation requires that they be tethered or tied with a safety line to the craft to insure their return. Gemini stores sufficient oxygen to re-fill its cabin when the astronauts return.

When the astronaut goes outside the spacecraft, the absence of gravity will keep him from falling, and a maneuvering unit strapped to his back will permit him to move around the outside of the craft. The space maneuvering unit contains small rocket engines to provide altitude control and maneuvering capability. The control box is attached to the front of the space suit.

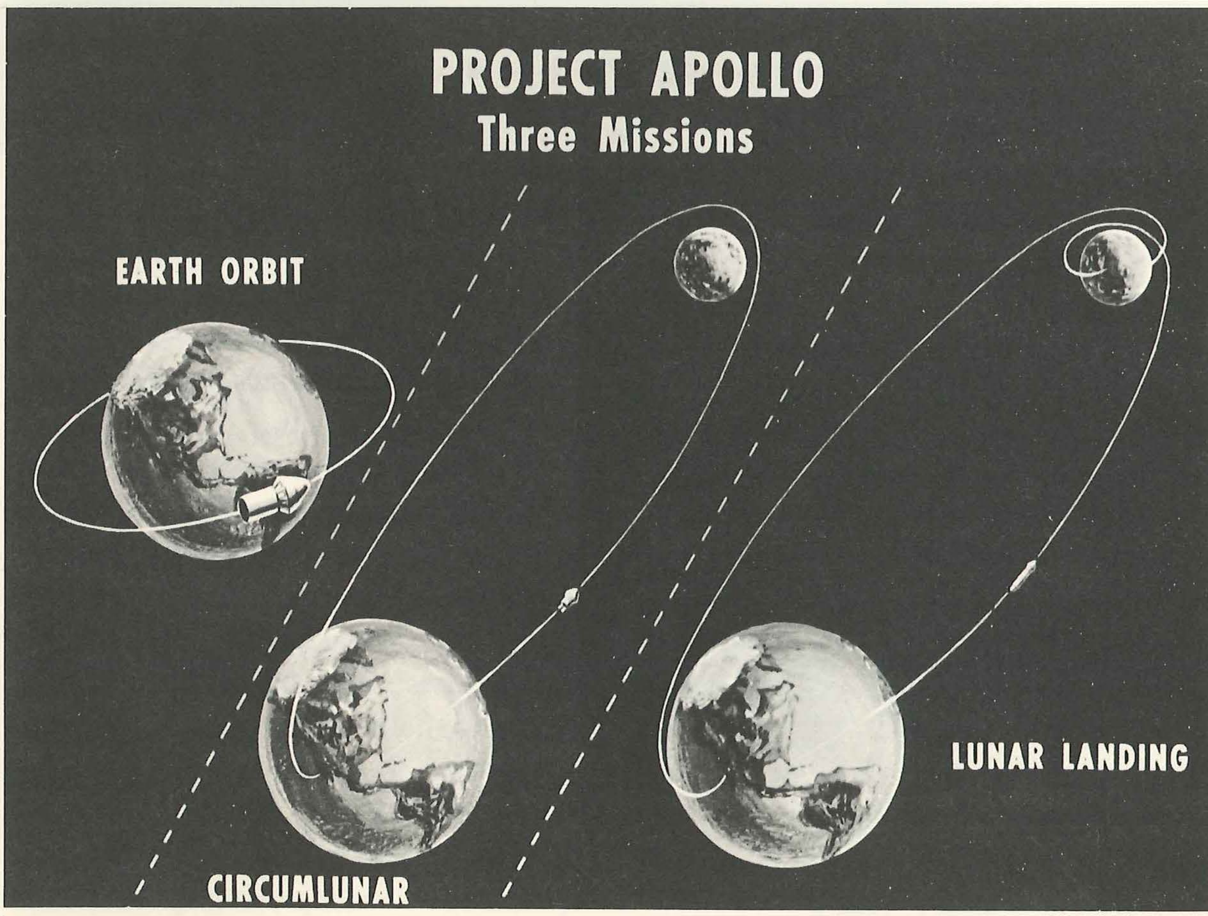
The repair of his craft while out of the cabin presents a problem to the astronaut. Because of weightlessness or the lack of resistance, using an ordinary wrench or screwdriver, for example, would cause the astronaut to rotate rather than the screw or bolt, while a welding torch would act like a rocket motor and would propel him away from his spacecraft. To overcome this, special tools for repairing spacecraft in

a state of weightlessness have been designed to do the pounding, turning, and twisting for the astronaut.

What will the Apollo spacecraft look like?

Projects Mercury and Gemini share a common limitation — they were built to operate in an earth orbit. Thus, Project Apollo is the biggest and most complex of the manned space flight projects. Named for the Greek god of poetry, music, and prophecy, its goal is to land American astronauts on the moon and bring them safely back to earth. The Apollo three-man spacecraft will be made up of three sections: the command module, the service module, and the lunar excursion module.

The command module can be compared to the passenger and crew compartment of an airliner. Its design will enable three men to work, eat, and sleep in it without wearing pressure suits. In addition to life-support equipment, it will contain windows, periscopes, controls, and instrument panels with which the astronauts can pilot their craft. It will have an air-lock to permit a pressure-suited crewman's exit into space. Of the three modules, only the command module will return to earth. Thus, it must be built to withstand the tremendous deceleration forces and intense heating caused by entry into earth's atmosphere. The module will have some maneuverability in the earth's atmosphere, and the astronauts will be able to guide their craft toward a selected landing field. The command



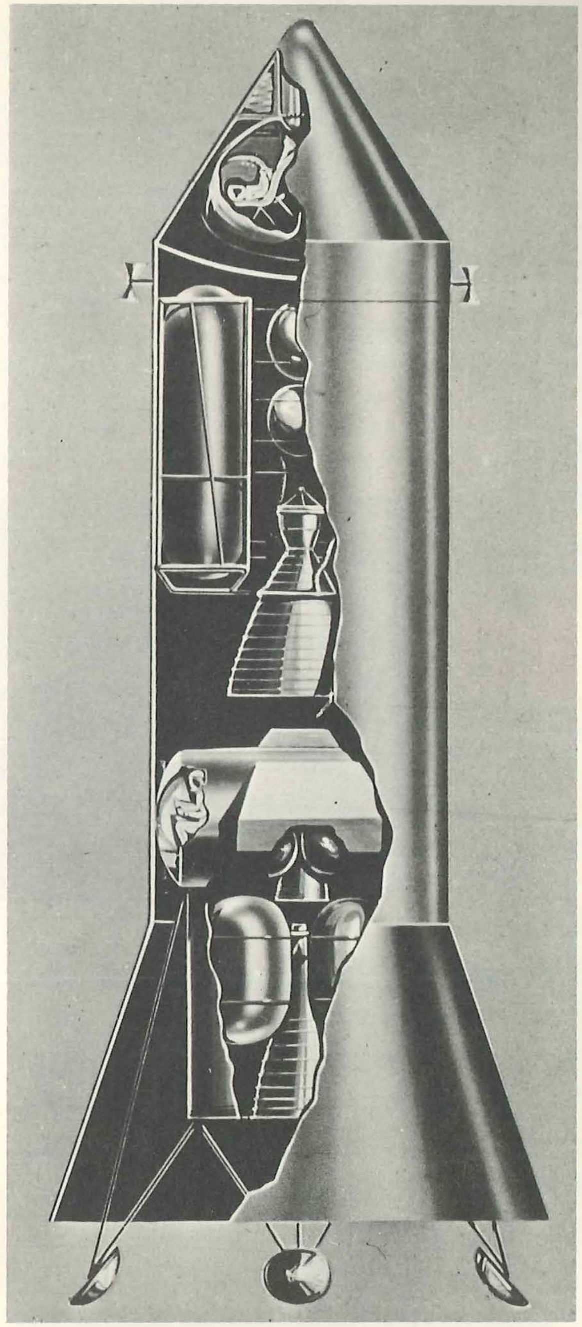
module will weigh about 5 tons, stand 12 feet tall, and have a base diameter of about 13 feet.

The service module will be equipped with rocket engines and fuel supplies so that the astronauts can propel their craft into and out of lunar orbit and change their course in space. This part of the Apollo spacecraft will weigh about 25 tons, measure 23 feet high, and be about 13 feet in diameter. It will be jettisoned just before entry into earth's atmosphere.

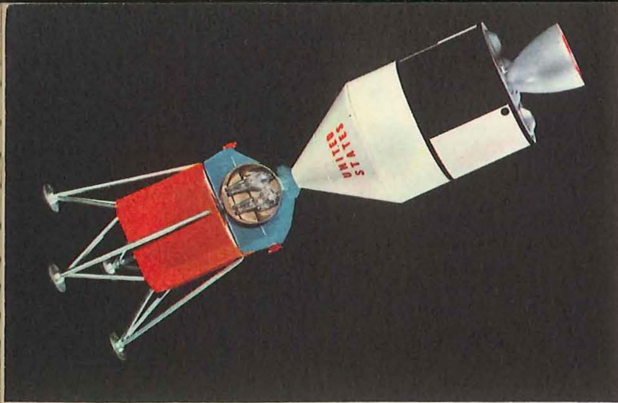
The lunar excursion module (LEM) is the space ferry that will take two Apollo astronauts down to the moon, carry them from the moon's surface into lunar orbit, and rendezvous with the Apollo command and service modules in lunar orbit. At launch from earth, the LEM will weigh about 12 tons. It will be some 15 feet high and have a base diameter of 13 feet. Among the LEM's equipment will be rockets for slowing down before landing on the moon, rockets for launch from the moon and for maneuvering in orbit, and five spider-like legs that will be extended to support the spacecraft on the moon's surface. These long spindly legs have given LEM the nickname of the "bug."

How will Apollo take the astronauts to the moon?

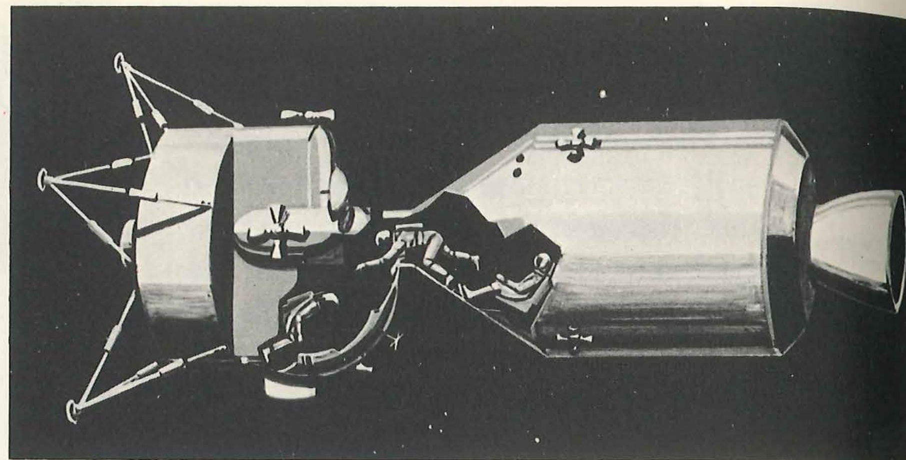
The giant Saturn V launch rocket will start Apollo on its lunar exploration mission. The entire assembly, including the rocket and spacecraft, will stand about 360 feet tall (more than the length of a football field) and weigh about 6,000,000 pounds at launch. Once the first Apollo spacecraft heads toward the moon, the three men aboard this 50-foot capsule, smaller than the *Santa María* in which Columbus sailed the Atlantic, will be carried into an environment unknown, uncharted, empty, silent, unfriendly,



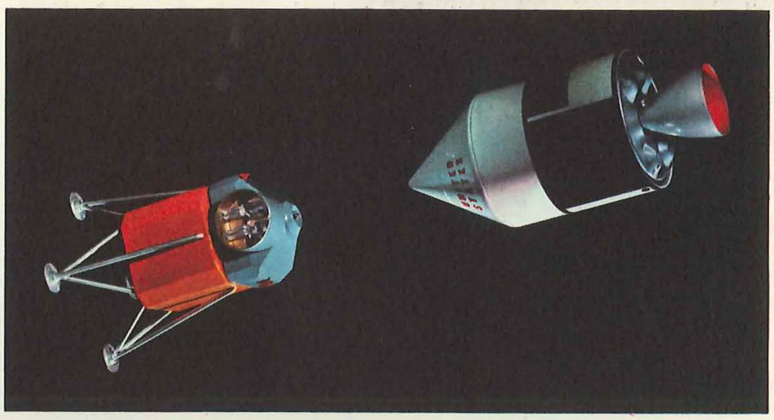
The Project Apollo spacecraft shows, from top to bottom, the Command Module, the Lunar Excursion Module, and the Lunar Propulsion Module.



Lunar Excursion Module (LEM) and Command and Service Module coast in lunar orbit.



Transfer of two astronauts from Command Module (CM) to LEM.



LEM is jettisoned from Command and Service Module.

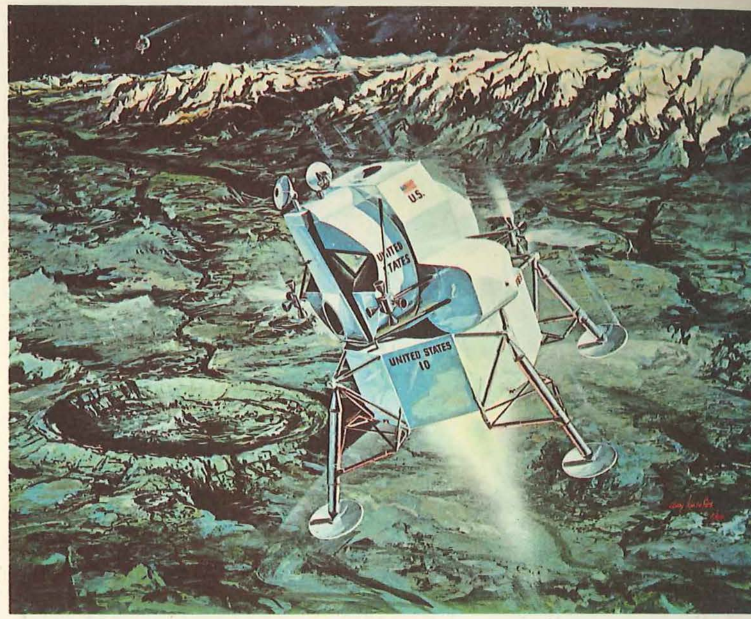
and perilous. The famous U. S. Air Force song hails "the wild blue yonder," but to astronauts in space, the "sky" does not appear blue. Out there, it is black, except for the sun and stars. Thus, as the Apollo astronauts head for the moon, they could well think, "Into the wild black yonder."

During the flight to the moon, the Apollo astronauts will have to pilot their ship by taking bearings on stars and other astronomical bodies. They will be helped by two old sailors' aids, a sextant and a telescope. They will take a fix on a star and a landmark on the earth or moon, and measure the angle between them. By feeding this reading into a computer on board the spacecraft, they will learn whether they are on course or have to make some corrections. Periodically, the astronauts will check their own physical and mental conditions, as well as the condition of every piece of operating equipment in their craft, and will make scientific observations. They will also report to earth frequently by radio, or possibly television.

Somewhere along their journey, two astronauts will have to climb outside the command module (wearing space suits and space maneuvering units, of course) and uncouple LEM from the tail end of Apollo and attach it to the nose end. The reason for change in positioning of the modules is this: The service module rocket cannot blast while LEM is in the way, but LEM can not be attached to the nose of Apollo when the mission starts. It would ruin

the smooth shape of the spacecraft, and Apollo would not move successfully through the atmosphere.

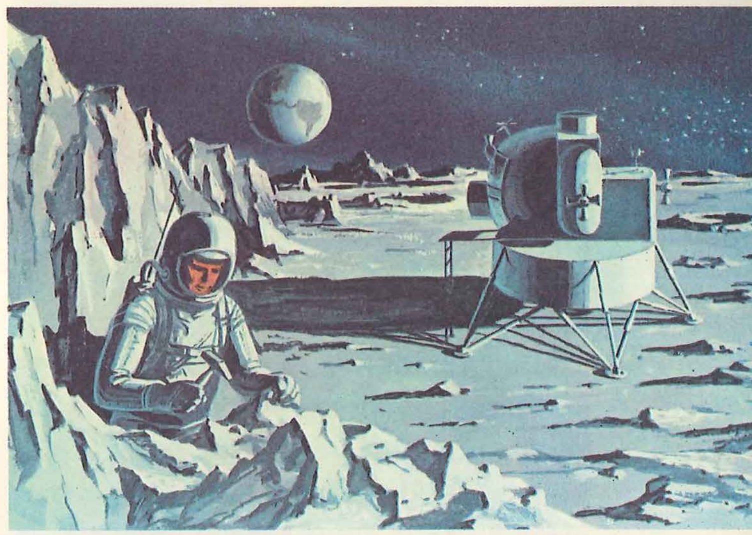
When they reach the moon's vicinity, the astronauts will rotate Apollo to a tail-forward position and fire a rocket in the service module to bring the spacecraft into a circular orbit about 100 miles above the moon. As Apollo coasts around the moon, two astronauts will enter LEM and detach it from command module; the third crewman remains with the mother ship as it continues to orbit the moon.



Astronauts in LEM fire rockets to slow their descent toward the moon.

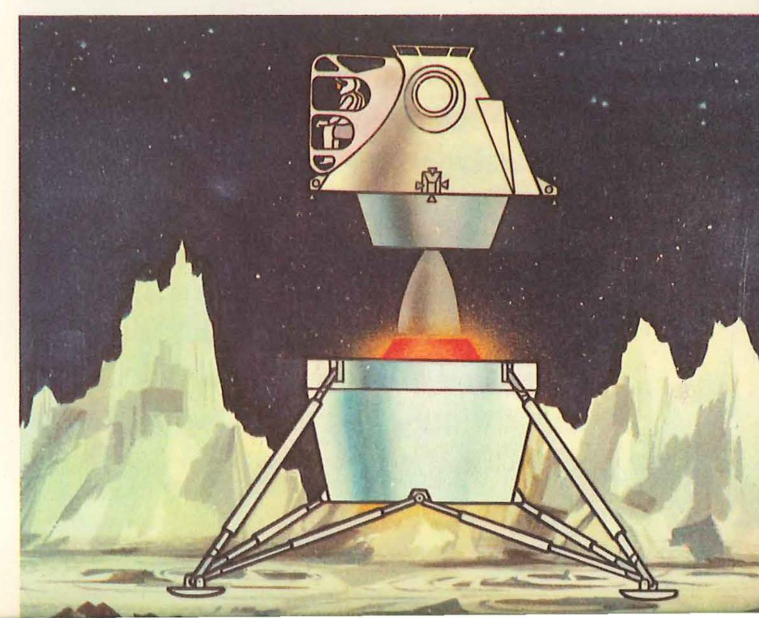
How will LEM land on the moon?

After leaving the mother ship, the two astronauts aboard LEM will fire rockets to slow their descent toward the moon. When only a few miles from the moon's surface, they will use a stabilizing device which will allow the craft to hover, thus permitting a final inspection of their landing area. At this point, the astronauts can rocket their ship back to the mother ship without landing, should they so decide. If they decide to land on the moon, they will extend their craft's landing gear, turn off the stabilizing device, and set LEM down gently on the lunar surface.



LEM has landed on the moon and while one astronaut will always stay inside the "bug," the other will explore the moonscape.

Once safely down, the astronauts will get out of LEM and collect samples of soil and rock, take photographs, measure magnetic fields, and carry out many other important experiments. While the astronauts will carry enough oxygen to stay on the moon for as long as four



Ascent rocket engines power LEM for lunar lift-off to reach moon orbit and final rendezvous with the Command Module.

days in the first moon landing, they will probably actually remain a much shorter time.

How will the astronauts get back to earth?

When the moon explorers wish to leave, they will enter LEM and blast off. LEM's legs and lower unit are left on the moon to reduce the weight that LEM's rockets have to push into orbit to rendezvous with the mother ship. After the two lunarnauts rejoin the astronaut in the command module, they will cast LEM loose to orbit around the moon. Then, they will fire a rocket in the service module to boost Apollo out of lunar orbit for the 60-hour-plus return to earth.

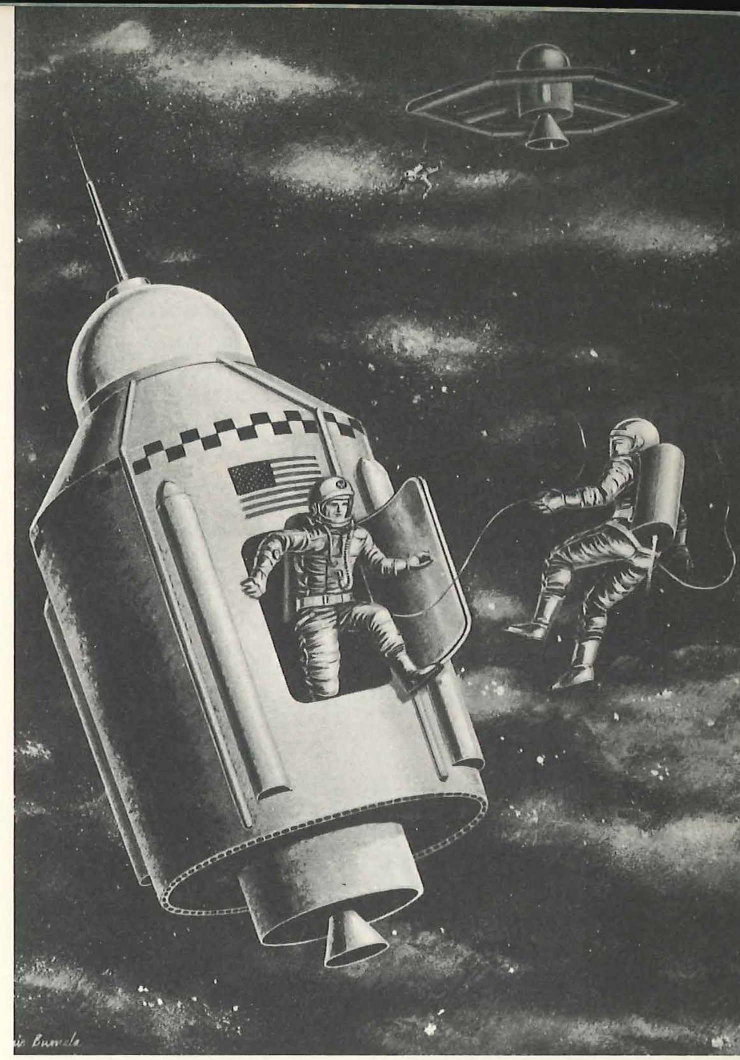
One of the most critical phases of the mission will be entry into earth's atmosphere. At a speed of 25,000 miles per hour (which will be the earth-approach velocity of a spacecraft returning from a lunar mission), Apollo must follow an extremely precise course called an "entry corridor." This corridor might be compared to the landing path of an airplane as it approaches a runway. If the plane comes in too low, it lands short of the runway; too high, and it overshoots the runway. In the case of Apollo, the landing path will be a corridor approximately 300 miles wide and 40 miles deep. If the lunar spacecraft reenters on the low side of this corridor, it will strike the atmosphere at too severe an angle, causing excessive heating and probable disintegration. If it comes in too high, on the upper side of the corridor, it will only skim the atmosphere, and will not slow down enough for re-entry. It would, instead, "bounce" off the top of the atmosphere, and hurtle back into space on a wide elliptical path. The astronauts will be able to operate rockets in the service module to help keep Apollo on a correct course. When they are in the entry corridor, they will jettison the service module to lighten the craft.

The command module will be subjected to extreme heat and stresses as the atmosphere slows its headlong flight. At about 60,000 feet, a small drogue parachute will open and stabilize the craft. At about 10,000 feet above earth, the large paraglider unit will open to lower the Apollo spacecraft gently to the expected landing area. Recovery forces will then race to pick up the astronauts for their triumphal return home.

The experience gained in manned exploration of the moon will no doubt serve as a basis for the beginning of manned exploration of the other planets of our solar system. There will be many similarities — and many differences. Among the latter are the considerably greater distances that must be traversed and the long periods of time that an astronaut must spend in the lonely voids of space. But for the time being, we still have a great deal to learn about and from our Gemini and Apollo flights.

What are space stations?

Before we can go visiting far-away planets, however, a system of space stations will have to be arranged. A space station can best be described as an artificial satellite on which man can live. It is different from either the Mercury or Gemini space-



Artist's concept of astronaut using "rocket pack maneuvering units" to help them fly between space stations and vehicles in orbit.

craft in that it is "permanent." It will stay in orbit without the possibility of re-entry into earth's atmosphere, which would destroy it. Astronauts will live on it for short periods of time. Their supplies and travel to and from, as well as their communications, would require a dependable earth-to-orbit supply and travel system.

Orbital space stations will have two important functions. First, as stated earlier, it will make possible the maintenance and repair of satellites in space as well as the refueling of spacecraft, the rotation of crews, and the transfer of food and cargo. Second, by using the facilities of the space station as a scientific laboratory and training center, it will permit research which is not possible on earth. As we now know, space flight simulation is most important. It is, however, severely handicapped when it must be done on the ground or in the atmosphere around earth. For example, weightlessness cannot be simulated for adequate periods of time, and it is not possible to duplicate the psychological effects of separation from earth and suspension in the loneliness of space. These two factors, however, are precisely the key that determines the final qualifications of astronauts. Their mental attitude, efficiency, endurance, and capacity for teamwork are intimately connected with their long-term response psychologically and physiologically to these two fundamental facts of life in space. Thus, space station colleges in the sky will some day serve as a laboratory for the selection and training of astronauts for long-duration missions in either space stations or lunar, or interplanetary, spacecraft.

When man has learned to move about freely in space, especially when he is able to move around outside of the spacecraft or space station that serves as his home base in space, there will be many activities that he can pursue. One of these will be engineering and construction in space. At the present time, space engineering, like astronaut training, is carried out generally on the ground. The engineered object, if it is a space vehicle or a spacecraft, is placed in orbit after the engineering has been

accomplished. In this approach, man stays on the ground, and sends his engineered object out into space. Much has been accomplished by this approach in the form of scientific satellites and space probes, weather satellites, communications satellites, navigation satellites, military applications of space technology, and even manned spacecraft.

But, one day, man will do some of his engineering and building right out in space. A lot of this activity may perhaps be more properly referred to as construction and maintenance, but the novelty of the problems and the environment to be faced will be such that, for a long time to come, the constructors and the maintainers will actually have to be "astronaut-engineers" in the true sense of the term.

Astronauts of the Future

The new profession of astronaut will continue to expand. It will provide a firm basis for the beginning of colonies on the moon and on the nearer planets of our solar system before the turn of the century. But even more important is the growth of the new science of astronautics. As we have already seen, this science is actually a combination of almost all the technological and scientific fields known to man. Almost everything — from astronomy to zoology and aerodynamics to sanitary engineering — is part of astronautics.

It is safe to say that astronautics is the highest form of technology and science in our modern civilization, the most concentrated application of man's capabilities achieved so far in human history. Earlier in this book, we compared Columbus' voyages to the New World to the flights of our astronauts. Columbus and the other European discoverers found vast wildernesses as they sailed around the globe, but at least the natural environment around them was basically the same as in their homeland. They had air to breathe, wild game or vegetables to eat, water to drink, a limited range of temperatures, and moderate sunshine. This is not true of our astronauts. Once beyond the atmosphere of earth, nothing out in space supports life. In fact, as you have read, everything threatens its very existence. Conditions, as they are known, on all other bodies of the solar system — be it the moon, other planets, or their moons — are equally hostile to life, or at least to earthly forms of life. It is hoped that the astronaut profession and the science of astronautics will combine to give man his greatest achievement — conquest of the universe.

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